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ART. I.—*Contributions to Meteorology: being results derived from an examination of the observations of the United States Signal Service, and from other sources;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Fifteenth paper, with Plate I.

[Read before the National Academy of Sciences, Washington, April 19, 1881.]

Reduction to sea-level of barometric observations made at elevated stations.

DURING the past eight years a large portion of my time has been devoted to investigating the course of storms in their progress across the Rocky Mountains, and in my first paper a storm was traced from Portland, Oregon, eastward to Lake Superior. During these eight years, I have had the constant services of a paid assistant, who has expended a vast amount of labor in attempting to discover the best method of tracing storms across the mountains. Some of the results of these investigations have been communicated in preceding papers, particularly Nos. 8, 9 and 13.

In order to study this subject more thoroughly, I have made a careful examination of the reduction to sea-level of the barometric observations made on Mt. Washington. I first prepared a table showing the reduction to sea-level, according to Dunwoody's Tables (S. S. Report for 1876, p. 354), for the entire

range of temperature and pressure experienced on Mt. Washington. I next computed the reduction according to the formula of Laplace, as developed in Guyot's Tables published by the Smithsonian Institution (Guyot's Meteorological Tables, series D, page 33), taking account of all the minute corrections. I next computed the reduction according to the formula of Plantamour, as developed in the Tables of Colonel Williamson (Professional Papers of the Corps of Engineers, No. 15). In order to compare these Tables with the actual observations, I took the monthly averages for Mt. Washington, as published in the Annual Reports of the S. S. for eight years (1872–1879); subtracted 6·36 inches for each month, and the remainder was regarded as the mean observed height. I took the mean between the reduced heights at Burlington, Vt. and Portland, Me., and used the result as representing the height of the barometer at sea-level under Mt. Washington. The difference between this result and the preceding gives the observed reduction of the Mt. Washington observations to sea-level. The mean of the temperatures at Burlington and Portland was taken to represent the temperature at the base of Mt. Washington, and the mean between the temperatures at the summit and base was regarded as the mean temperature of the column of air extending from the summit of the mountain to sea-level. When several months of the eight years observations gave about the same temperature and pressure, they were combined in a single mean. I thus obtained thirty values of the reduction from summit to sea-level, for a considerable range of temperature and pressure.

In order to extend the comparison to the greatest possible range of temperature and pressure, I selected the following list of dates from the published volumes of the tri-daily observations, now embracing a period of thirty-six months. 1. All the dates on which the thermometer on Mt. Washington fell ten degrees below zero, and also all the dates on which the thermometer at Burlington or Portland fell to ten degrees above zero. 2. All the dates on which the thermometer on Mt. Washington rose as high as 55°, and all the dates on which the thermometer at Burlington or Portland rose to 80°. 3. All the dates on which the barometer on Mt. Washington or at Burlington or Portland sunk 0·40 inch below its normal height; 4. All the dates on which the barometer at either of the stations rose 0·30 inch above its normal height. These four classes together embraced 423 days. For each of these dates, the mean pressure on Mt. Washington (from the three daily observations) was determined; the mean pressure at Burlington and Portland, and also the mean temperature at Burlington and Portland. These results enabled me to extend the observed reduc-

tion to sea-level from the barometric height 22·7 inches to 24·2 inches and from the temperature −10° to +65°. In order to smooth down the inequalities of the observed numbers, I took the mean between each three consecutive numbers corresponding to the same temperature, and substituted this result for the middle number. It is presumed that the results thus obtained represent pretty nearly the results which would be obtained from observations extending over a long term of years.

The results thus described are exhibited in the following Table, in which the height of the barometer on Mt. Washington, from 22·7 to 24·2 inches is given at the top of the table, and the mean temperature of the air column from −10° to +65° is given on the left margin. Corresponding to each temperature given in the table are four horizontal lines, the first of which (marked D), gives the reduction to sea-level as computed from Dunwoody's Tables; the second horizontal line (marked L), shows the reduction computed from Guyot's Tables founded on the formula of Laplace; the third horizontal line (marked P), shows the reduction computed from Williamson's Tables, which are based on those of Plantamour; the fourth horizontal line (marked O), shows the reduction deduced from actual observations as above described.*

An examination of this table shows the following results:

1. Dunwoody's Tables accord very well with those derived from the formula of Laplace, the differences ranging from +0·011 inch to −0·041 inch.

2. The differences between the formulas of Laplace and Plantamour range from +0·030 inch to +0·103 inch, the reduction by Laplace being on an average 0·053 inch greater than by Plantamour.

3. The reductions deduced from the actual observations differ very much from either of the values above computed; the differences from Laplace ranging from +0·263 to −0·105 inch. These differences follow a remarkable law. According to the formula of Laplace, when the pressure on Mt. Washington increases from twenty-three inches to twenty-four inches without any change of temperature, the reduction to sea-level is increased by $\frac{1}{23}$ part of its former value. Observations, however, show that the actual increase in the amount of the reduction is very small, being on an average only *one-seventh* as great

* Since this article was written I have been informed that the constant 6·36 inches for reducing the Mt. Washington observations to sea-level began to be used March 1st, 1874, and that for the two preceding years the constant 6·31 inches had been used. Thus it appears that for a period of eighteen months, I had made the Mt. Washington barometric observations too low by 0·05 inch, which would indicate an average error of about 0·02 inch for the entire period of the observations. This would correspond to an average error of about 0·001 inch in the column of observed reductions to sea-level, which is so small an error that I have not considered it necessary to re-compute the entire series of observations.

Reduction to sea-level of barometer on Mt. Washington, elevation 6285 feet.

Ther.		22·7	22·8	22·9	23·0	23·1	23·2	23·3	23·4	23·5	23·6	23·7	23·8	23·9	24·0	24·1	24·2
	D	6·886	6·912	6·938	6·964	6·990	7·016	7·043	7·070	7·096	7·123	7·150	7·177				
—10°	L	6·875	6·905	6·935	6·965	6·996	7·026	7·057	7·087	7·117	7·148	7·176	7·208				
	P	6·778	6·808	6·837	6·867	6·897	6·926	6·956	6·986	7·016	7·046	7·076	7·105				
	O	7·138	7·142	7·146	7.150	7·155	7·155	7·155	7·155	7·155							
	D	6·785	6·811	6·837	6·863	6·889	6·916	6 943	6·969	6·995	7·022	7 050	7·079	7·108			
—5	L	6·779	6·809	6·839	6·870	6·900	6·930	6·960	6·990	7·019	7·049	7·079	7·109	7·139			
	P	6·691	6·721	6·751	6·781	6·810	6 840	6·869	6·898	6·928	6·958	6·987	7·016	7·045			
	O	7·002	7·011	7·020	7·029	7·045	7·046	7·046	7·047	7·047	7·052	7·058					
	D	6·697	6·723	6·749	6·775	6·801	6·828	6·855	6·881	6·907	6·933	6·960	6·987	7·014	7·041		
0	L	6·688	6·717	6·747	6·776	6·806	6·836	6·865	6·895	6·924	6·954	6 983	7·013	7 042	7·072		
	P	6·608	6·637	6·666	6·696	6·726	6·755	6·784	6·814	6·844	6·873	6·902	6·932	6·961	6 990		
	O	6·882	6·890	6·904	6·917	6·932	6·938	6 940	6·943	6·943	6·943	6·943					
	D	6 602	6·628	6·655	6 681	6·706	6·731	6·756	6·782	6·807	6·833	6·859	6·886	6 913	6·939		
+5	L	6·599	6·628	6·657	6·686	6·715	6·744	6·773	6·802	6·831	6·860	6.889	6·918	6·947	6·976		
	P	6·525	6·554	6·582	6·611	6·640	6·669	6·698	6·727	6·756	6·785	6·814	6·843	6·872	6·901		
	O	6·790	6·800	6·811	6·821	6·825	6·825	6·826	6·829	6.829	6·829	6·829					
	D	6·513	6·540	6·567	6·593	6·618	6·643	6·668	6·694	6·719	6·745	6·771	6·798	6·825	6·851	6·877	
10	L	6·512	6·540	6·569	6·598	6·627	6·656	6·684	6·712	6·741	6·770	6·798	6·827	6·856	6·884	6·913	
	P	6·446	6·474	6·503	6·531	6·559	6·588	6·616	6·645	6·673	6·702	6·731	6·759	6·788	6·816	6·845	
	O	6·725	6·725	6·725	6·725	6·725	6·725	6·725	6·725	6·731	6·732	6·733	6·741				
	D	6·430	6·455	6·480	6·505	6·530	6·555	6·580	6·606	6·631	6·657	6·683	6 710	6·737	6·763	6·788	6·813
15	L	6·427	6·455	6·484	6·512	6·540	6·569	6·597	6·625	6·653	6·682	6·710	6·739	6·767	6·795	6·823	6·851
	P	6·368	6·396	6·425	6·453	6·481	6·509	6·537	6·565	6·593	6·621	6·650	6·678	6·706	6·834	6·762	6·790
	O	6·642	6·642	6·643	6·643	6·643	6·643	6·643	6·644	6·647	6·655	6·667	6·675	6·681			
	D	6·348	6·373	6·398	6·423	6·448	6·474	6·499	6·524	6·549	6·574	6·599	6·624	6·650	6·675	6·700	6·725
20	L	6·344	6·372	6·400	6·428	6·456	6·484	6·512	6·540	6.567	6·595	6·623	6·651	6·679	6·707	6·735	6·763
	P	6·292	6·320	6·347	6·375	6·403	6·431	6·458	6·486	6 513	6·541	6·569	6·597	6·624	6·652	6·680	6·708
	O	6·560	6·560	6·563	6·567	6·571	6·574	6·577	6·580	6·586	6·592	6·598	6·599	6·600	6·602		
	D	6·266	6·291	6·316	6·341	6·366	6·390	6·414	6·438	6·462	6·487	6·512	6·537	6·562	6·587	6·612	6·637
25	L	6·265	6 292	6·319	6·347	6·374	6·402	6·429	6·457	6·484	6·512	6·539	6·567	6·594	6·622	6·649	6·677
	P	6·216	6·243	6·271	6·298	6·326	6·353	6·381	6·408	6·436	6·464	6·501	6·529	6·547	6 574	6·602	6·629
	O		6·490	6·494	6·497	6·499	6 502	6·509	6·513	6·517	6·521	6·528	6·535	6·541	6·546		
	D	6·186	6·210	6·234	6·258	6·282	6·306	6·330	6 355	6·380	6·405	6.430	6·455	6·480	6·505	6·530	6·555
30	L	6·185	6·212	6·239	6·266	6·293	6·321	6·348	6.376	6·403	6·430	6·457	6·484	6·511	6·539	6·566	6·594
	P	6·142	6·170	6·197	6·224	6·251	6·278	6·306	6·333	6·360	6·387	6·414	6·441	6·468	6·495	6·522	6 550
	O			6·417	6·418	6 419	6·425	6·435	6·442	6·447	6·451	6·461	6·471	6·478	6·488	6·499	
	D	6·106	6·130	6·154	6·178	6·202	6·226	6 250	6·274	6·298	6·323	6·347	6·372	6·396	6·421	6·446	6·471
35	L	6·108	6·135	6 162	6·188	6·215	6·242	6·269	6·296	6·323	6·350	6·377	6·404	6·431	6·458	6·485	6·512
	P	6·069	6·096	6·123	6·149	6·176	6·203	6·230	6·257	6·283	6·310	6·337	6·364	6·391	6·418	6·445	6·472
	O					6·346	6·354	6·362	6·368	6·374	6·379	6·385	6·392	6·403	6·413	6·420	
	D	6·036	6·060	6·084	6·108	6·132	6·156	6·180	6·204	6·228	6·252	6·276	6·300	6·324	6·348	6·372	6·396
40	L	6·033	6·059	6·086	6·112	6·139	6·166	6·192	6 219	6·246	6·273	6·299	6·326	6·352	6·379	6·405	6·431
	P	5·997	6·023	6·050	6·076	6·103	6·130	6·156	6·182	6·209	6·236	6·262	6·289	6·315	6·342	6·368	6·394
	O						6·300	6·302	6·304	6·306	6 308	6·310	6·312	6·319	6·329	6·330	6·335
	D	5·961	5·985	6·008	6·032	6·055	6·079	6·102	6·126	6·149	6·173	6·196	6·220	6·243	6·267	6·290	6·314
45	L	5·960	5·986	6·013	6·039	6·065	6·091	6·117	6 144	6·170	6·196	6·222	6·249	6·275	6·302	6·328	6·354
	P	5·926	5·952	5·979	6·006	6·032	6·058	6·084	6·111	6·137	6·163	6·189	6·215	6·241	6·268	6·295	6·321
	O								6·240	6·240	6·241	6·241	6·242	6·244	6·249	6·254	6·259
	D	5·895	5·918	5·941	5·964	5·987	6 010	6·033	6·056	6 079	6·102	6·126	6·149	6·173	6·196	6·220	6·243
50	L	5·889	5·915	5·941	5·966	5 992	6·018	6·044	6·070	6 096	6·122	6·148	6·174	6·200	6 226	6·252	6·278
	P	5·857	5·883	5·908	5·934	5·960	5·986	6·012	6 038	6·064	6·090	6·116	6·142	6·168	6·194	6·221	6·247
	O									6·177	6·177	6·177	6·178	6 178	6·182	6·189	6·194
	D	5·820	5·843	5·866	5·889	5·912	5·935	5·958	5·981	6·004	6.027	6·050	6·073	6·096	6·119	6·142	6.165
55	L	5·819	5·845	5·871	5·896	5·922	5·947	5·973	5·999	6 024	6.050	6·075	6·101	6·127	6·153	6·178	6·204
	P	5·788	5·813	5·839	5·865	5·890	5·916	5·942	5·968	5·994	6.020	6·045	6·071	6·097	6·123	6·148	6·173
	O										6 113	6·113	6·113	6·113	6·118	6·124	6·129
	D	5·751	5·774	5·797	5·820	5·843	5·866	5·888	5·911	5·934	5·957	5·980	6·003	6·025	6·048	6·071	6·094
60	P	5·751	5·776	5·802	5·827	5·853	5·878	5·903	5·929	5·954	5·979	6·004	6·030	6·055	6·081	6·106	6·132
	L	5·719	5 744	5·770	5·795	5·821	5·847	5·872	5·898	5·923	5·948	5·973	5·999	6·025	6·051	6·076	6·101
	O										6·042	6·044	6·045	6·045	6·046	6·052	6·057
	D	5·683	5·706	5·729	5·752	5·774	5·796	5 819	5·842	5·865	5·887	5·910	5·933	5·955	5·978	6·001	6·023
65	L	5·685	5·710	5·735	5·760	5·785	5·810	5·835	5·860	5·885	5·910	5·935	5·960	5·985	6·010	6·035	6·060
	P	5·651	5·676	5·701	5·726	5·751	5·776	5·802	5·827	5 852	5·877	5·902	5·927	5·952	5·977	6·002	6·028
	O										5·973	5·973	5·973	5·975	5·977	5·981	5·986

as that given by the formula of Laplace. The influence of temperature on the reduction to sea-level, as deduced from the observations, differs but little from that given by the formula of Laplace. At the highest temperatures, the observed reduction accords with that computed by the formula when the pressure at sea-level is 29·8 inches; and at the lowest temperatures the agreement occurs when the pressure at sea-level is 30·7 inches. Thus we see that the true reduction of barometric observations to sea-level for Mt. Washington depends mainly upon temperature.

The observed values of the reduction to sea-level given in the table on page 4 are in all cases the means of a considerable number of observations. In some cases the observed values differ very much from the means here given. In order to learn the magnitude of these differences and to study the circumstances under which they occur, I proceeded as follows: I selected all those cases (for the thirty-six months of the tridaily observations) in which the reduction computed by Dunwoody's Tables differed by 0·25 inch from the observed reduction. The number of these cases was ninety-six. As this table seemed too large for publication, I selected those cases in which the difference amounted to at least 0·3 inch and for these cases the reduction to sea-level was rigorously computed by the formula of Laplace. The results are given in the following table, in which column 1st shows the number of the storm; column 2d shows the date of the observation; column 3d shows the observed height of the barometer on Mt. Washington, not reduced to sea-level. This observed height was obtained by subtracting 6·31 inches from the published heights for all dates preceding March, 1874, and subtracting 6·36 inches for subsequent dates. Column 4th shows the mean temperature of the air column from the summit to the base of the mountain $\left(\frac{2W+B+P}{4}\right)$; column 5th shows the observed reduction to sea-level $\left(\frac{B+P}{2}-W\right)$; column 6th shows the reduction to sea-level computed by Laplace's formula, for a height 6,285 feet, with a barometer and temperature as given in columns 3 and 4; column 7th shows the reduction according to the table on p. 4, in the lines marked O; column 8th shows the difference between the numbers in columns 5 and 6; column 9th shows the difference between the numbers in columns 5 and 7; column 10th shows (in hours) how much the minimum pressure on Mt. Washington occurred later than the half sum of the dates of minimum at Burlington and Portland; column 11th shows the direction and force of the wind on Mt. Washington.

The number of cases in this table is 40, of which 8 occurred in November; 11 in December; 12 in January; 2 in Febru-

Cases in which the reduction to sea-level was unusually great.

No.	Date.	Mt.Was. Barom.	Mean Temp.	Red. to sea-lev. Obs.	Red. to sea-lev. Lapl.	Red. to sea-lev. Table	Difference. Lapl.	Difference. Table	Low ret'd.	Mt. Wash. Wind.
1	1872 Nov. 7.3	22·78	30°·2	6·49	6·19	6·41	0·30	0·08	8	N.W. 65
	8.1	·81	31·2	6·54	6·18	6·40	·36	·14	8	N.W. 48
	8.2	·96	34·2	6·49	6·18	6·35	·31	·14	8	N. 65
	9.1	23·12	29·7	6·65	6·29	6·42	·36	·23	8	N.W. 58
	9.2	·24	29·7	6·65	6·32	6·43	·33	·22	8	W. 78
2	29.2	22·89	22·0	6·81	6·35	6·53	·46	·28	4	S.W. 35
	30.1	·63	10·2	6·81	6·47	6·72	·34	·09	4	N.E. 45
	30.3	·73	9·5	6·89	6·51	6·73	·38	·16	4	W. 48
	Dec. 1.1	·85	12·5	6·99	6·50	6·68	·49	·31	4	N. 52
3	3.2	23·14	26·5	6·66	6·35	6·48	·31	·18	4	S.E. 60
	4.1	·24	21·7	6·78	6·45	6·55	·33	·23	4	W. 58
4	10.1	22·78	7·2	6·87	6·57	6·76	·30	·11	16	W. 59
5	15.2	23·12	20·0	6·82	6·45	6·57	·37	·25	7	N. 68
6	22.2	·05	— 1·2	7·13	6·77	6·95	·36	·18	13	W. 43
7	24.3	·05	—13·0	7·44	7·00	7·22	·44	·22	?	W. 44
8	28.1	22·75	—10·7	7·21	6·89	7·16	·32	·05	15	N.E. 60
9	1873 Jan. 6.2	23·14	15·0	6·96	6·54	6·64	·42	·32	9	W. 60
10	11.3	·06	— 1·2	7·10	6·80	6·95	·30	·15	12	N. 76
11	29.1	·10	— 2·2	7·14	6·83	6·97	·31	·17	4	W. 54
12	Feb. 10.1	22·96	— 2·5	7·18	6·80	6·96	·38	·22	?	N.W. 77
	10.2	23·01	0·7	7·08	6·75	6·89	·33	·19	?	N.W. 103
13	March 16.2	22·78	21·7	6·67	6·32	6·54	·35	·13	13	W. 28
	16.3	·74	17·2	6·88	6·39	6·61	·49	·27	13	N.W. 56
	17.1	·87	14·2	6·95	6·47	6·65	·48	·30	13	W. 56
	17.2	23·15	17·7	6·81	6·49	6·60	·32	·21	13	N.W. 25
14	24.1	22·92	8·0	7·07	6·60	6·76	·47	·31	13	W. 48
15	Dec. 10.1	23·33	23·7	6·78	6·44	6·53	·34	·25	9	N.W. 62
16	1874 April 30.2	22·67	23·2	6·72	6·28	6·51	·44	·21	4	N.W. 130
	30.3	·72	23·5	6·70	6·30	6·51	·40	·19	4	N.W. 115
17	Dec. 29.2	23·02	11·2	6·88	6·58	6·70	·30	·18	18	N.W. 80
	30.2	·01	— 5·2	7·22	6·87	7·03	·35	·19	18	N.W. 98
18	1875 Jan. 9.3	22·70	— 8·7	7·26	6·85	7·10	·41	·16	8	N.W. 100
19	14.1	·91	12·0	6·89	6·54	6·69	·35	·20	28	N.W. 70
	14.3	·82	— 4·0	7·13	6·80	6·99	·33	·14	28	N.W. —
	15.1	·71	—15·5	7·42	6·98	7·29	·44	·13	28	N.W. —
	15.2	·95	—10·2	7·25	6·95	7·14	·30	·11	28	N.W. —
	15.3	23·00	— 7·5	7·24	6·92	7·09	·32	·15	28	N.W. —
20	17.1	22·91	—11·2	7·28	6·96	7·18	·32	·10	12	N.W. —
21	25.2	·93	13·0	6·91	6·53	6·68	·38	·23	9	N.W. 80
	26.2	·95	0·0	7·14	6·76	6·91	·38	·23	9	N.W. 94

ary; 5 in March and 2 in April. During the six months from May to October inclusive, no case occurred in which the observed reduction differed 0·3 inch from that computed by the Laplace formula, and four-fifths of these cases occurred in the months of November, December and January. Fifteen of these cases occurred at the 7.35 A. M. obs.; 16 occurred at the 4.35 P. M. obs.; and nine at the 11 P. M. obs., indicating that the diurnal change of temperature has an appreciable influence upon this phenomenon, but that it is mainly dependent upon some other cause. It will also be noticed that in every one of

these cases the observed reduction was greater than that computed from the Laplace formula. There is not a single instance in which the observed reduction was 0·3 inch less than that computed from the Laplace formula.

The mean of the numbers in column 8th is 0·362 inch, and the mean of the numbers in column 9th is 0·190 inch, showing that when the reduction is computed from the table on page 4, the average error is but little more than half as great as when computed from the Laplace formula. There are ten cases, out of 3,285 observations, in which the error of the reduction by the Laplace formula exceeds 0·4 inch, and there are only three cases in which the error of the reduction by the table page 4, exceeds 0·3 inch. This table is therefore a great improvement upon Laplace and also upon any other table of reductions hitherto published.

All these cases enumerated on page 6 occurred during the progress of storms which were generally of considerable violence. In every case, the barometric minimum on Mt. Washington occurred later than it did near the level of the sea, the average retardation amounting to more than eleven hours. In most of the cases the barometer at the lower stations had passed the minimum, and in about half of the cases had risen to thirty inches, while the barometer on Mt. Washington had risen comparatively little. In a large part of the cases the temperature was unusually low and the wind on Mt. Washington was very high. In two cases the temperature at Burlington was lower than it was on Mt. Washington, and in other cases the difference of temperature was very small. In 1873, Jan. 29.1, the thermometer at Burlington was 9° lower than on Mt. Washington; on Feb. 10.1, it was 2° lower; in 1872, Dec. 24.3, the temperature at both stations was the same; and in 1873, March 24.1, it was only 2° colder on Mt. Washington than at Burlington. These observations help to explain in a few of the cases, why there was an increased pressure at the lower stations which did not extend to the summit of Mt. Washington. A cold stratum of air whose height was less than 6,000 feet, flowed along the surface of the earth, increasing the barometric pressure at the lower stations, but producing no decided effect upon the pressure at the summit of Mt. Washington.

It will also be observed that in half of these cases the wind on Mt. Washington was from the northwest; and in four-fifths of the cases it was either west or northwest. The velocity of the wind was also remarkable, the average being sixty-six miles per hour, and in four instances the velocity was one hundred miles or more. In 1875, from Jan. 14th to 17th, the velocity of the wind was not reported, but it is presumed to have been about one hundred miles per hour. It is evident, therefore,

that these cases of low pressure on Mt. Washington were generally the result of great storms in progress, and in most of the cases the violence of the storm had ceased at the lower stations while it continued unabated on Mt. Washington. The Danish weather maps which show the isobars for the Atlantic Ocean since March, 1874, assist us in understanding the cause of these high winds on Mt. Washington. They show that an area of low pressure prevailed on the east side of the mountain, generally near Nova Scotia or Newfoundland; and the winds on Mt. Washington were controlled by this low area long after the high winds at Burlington and Portland had subsided.

We thus find that if the barometric observations on Mt. Washington are reduced to sea-level by the table on page 4, the results will rarely differ one-tenth of an inch from actual observations made near sea-level. Exceptional cases will sometimes occur; but great anomalies are confined to the colder months of the year, and seldom occur except during the progress of violent storms.

In order to ascertain whether the law respecting the reduction of barometric observations to sea-level, which has been discovered for Mt. Washington, holds true for other mountains, I made a comparison of the observations on Pike's Peak, when reduced to the altitude of Denver. The altitude of Pike's Peak, as determined by a preliminary computation which differs slightly from the final result given on page 18 is 14,056 feet, and that of Denver is 5,262 feet. The materials employed for this comparison consisted of the tri-daily observations from November, 1873, to January, 1875, and from January, 1877, to July, 1877 (22 months), and the monthly means from November, 1873, to June, 1879, published in the annual reports of the Signal Service. These materials were reduced in the manner already described in the case of Mt. Washington. The table on page 9 shows the reduction from Pike's Peak to Denver for a range of the barometer from 17·1 inches to 18·2 inches on Pike's Peak, and for a mean temperature of the air-column between the two stations from $-10°$ to $+60°$. Corresponding to each temperature are two horizontal lines, one of which is marked L, showing the reduction computed from Guyot's Tables based on the formula of Laplace (Guyot's Met. Tables, series D, p. 33), and the other, marked O, shows the reduction deduced from actual observations.

We see from this table that the increase in the value of the reduction to sea-level resulting from an increase of pressure on Pike's Peak is very small, being, on an average, less than *one-fifth* of that computed from the formula of Laplace. In this particular the results accord very closely with those before found for Mt. Washington. The influence of temperature

upon the amount of the reduction differs somewhat from that given by the formula. While the pressure at Pike's Peak remains unchanged, the observed change in the reduction to Denver, resulting from a change of temperature, is 33 per cent less than the computed reduction. At the highest temperatures the observed reduction accords with that computed by the formula when the barometer at Denver stands at 24·95 inches; and at the lowest temperatures the agreement occurs when the barometer at Denver stands at 24·45 inches.

Reduction of barometer from Pike's Peak (elevation 14,056 feet) to Denver (elevation 5,262 feet).

Therm.		17·1.	17·2.	17·3.	17·4.	17·5.	17·6.	17·7.	17·8.	17·9.	18·0.	18·1.	18·2.
−10°	L	7·651	7·696	7·741	7·786	7·830	7·875	7·920	7·965	8·010	8·055	8·100	8·145
	O	7·565	7·572										
− 5	L	7·540	7·584	7·628	7·673	7·717	7·762	7·806	7·850	7·894	7·938	7·982	8·027
	O	7·511	7·517	7·523									
0	L	7·433	7·477	7·520	7·564	7·607	7·651	7·694	7·738	7·781	7·825	7·868	7·912
	O	7·436	7·440	7·442	7·442	7·445							
+ 5	L	7·329	7·372	7·415	7·458	7·501	7·544	7·586	7·629	7·672	7·715	7·758	7·801
	O	7·353	7·359	7·363	7·364	7·364	7·364						
10	L	7·227	7·269	7·312	7·354	7·396	7·439	7·481	7·523	7·566	7·608	7·651	7·693
	O	7·278	7·284	7·291	7·291	7·291	7·290	7·289	7·287				
15	L	7·128	7·170	7·212	7·253	7·295	7·337	7·378	7·420	7·462	7·504	7·546	7·588
	O	7·212	7·216	7·218	7·223	7·228	7·228	7·228	7·228				
20	L	7·032	7·073	7·114	7·155	7·197	7·238	7·279	7·320	7·361	7·402	7·443	7·485
	O		7·12.	7·155	7·170	7·177	7·180	7·186	7·188				
25	L	6·938	6·979	7·019	7·060	7·101	7·141	7·182	7·222	7·263	7·303	7·344	7·385
	O			7·087	7·102	7·120	7·126	7·127	7·130	7·133			
30	L	6·847	6·887	6·927	6·967	7·007	7·047	7·088	7·128	7·168	7·208	7·248	7·288
	O				7·033	7·043	7·064	7·067	7·070	7·076			
35	L	6·758	6·798	6·837	6·877	6·916	6·956	6·995	7·035	7·074	7·114	7·153	7·193
	O				6·968	6·976	6·993	7·010	7·017	7·030	7·036		
40	L	6·671	6·710	6·749	6·788	6·827	6·866	6·905	6·944	6·983	7·023	7·062	7·101
	O					6·914	6·930	6·939	6·957	6·972	6·980		
45	L	6·587	6·626	6·664	6·703	6·741	6·780	6·818	6·857	6·895	6·934	6·972	7·011
	O						6·860	6·867	6·884	6·908	6·920		
50	L	6·505	6·543	6·581	6·619	6·657	6·695	6·733	6·771	6·809	6·848	6·886	6·924
	O							6·797	6·809	6·842	6·857	6·860	
55	L	6·425	6·463	6·500	6·538	6·575	6·613	6·650	6·688	6·725	6·763	6·801	6·838
	O								6·754	6·772	6·795	6·802	
60	L	6·346	6·383	6·420	6·457	6·494	6·532	6·569	6·606	6·643	6·680	6·718	6·755
	O									6·733	6·738	6·744	6·750

In order to test the preceding results under different circumstances I selected two stations near the Pacific coast, viz: Sacramento and Summit. Sacramento is situated in lat. 38° 35′, long. 121° 31′, and is elevated 31 feet above the sea. Summit is situated on the Central Pacific Railroad in lat. 39° 20′, long.

120° 5′, and is elevated 7,017 feet above the sea. At these stations meteorological observations were made three times a day for three years in connection with the Geological Survey of California under the direction of Prof. Josiah D. Whitney. The monthly means of the barometer and thermometer were published by Prof. Whitney in a volume entitled "Contributions to Barometric Hypsometry," and the original observations have been placed in my hands by Prof. Whitney. For the purpose of comparing these observations, a table was prepared showing for each day of the three years—1. the height of the barometer at Summit according to the mean of the three daily observations reduced to 32° F.; 2. the mean of the temperatures at Summit and Sacramento for each day, according to the three daily observations; and 3. the difference between the mean barometric heights at Summit and Sacramento for each day. These results were then divided into classes according to temperature in such a manner that each class should include a range of five degrees, and the middle temperature should be some multiple of five. The observations of each of these classes were then compared in respect to barometric pressure at Summit, so that all those observations which were made at nearly the same pressure were grouped together, and an average was taken of the numbers in each of these groups. In this way I obtained the reduction to Sacramento corresponding to a considerable range of temperature and pressure. The inequalities of the resulting numbers were somewhat smoothed down by applying the method described on page 3. The final results are given in the table on page 11 which shows the reduction of the barometer from Summit to Sacramento for pressures ranging from 22·7 to 23·6 inches; and for temperatures of the air-column from Summit to Sacramento ranging from 25° to 80° F. Corresponding to each temperature are given two horizontal lines marked L and O; the former shows the reduction computed from the formula of Laplace, the latter shows the reduction deduced from the actual observations.

An examination of this table shows that the reduction of the barometer from Summit to Sacramento instead of *increasing* with an increase of pressure, as required by the formula of Laplace, invariably *decreases;* and the average observed decrease is seven-eighths of the increase computed from the formula; and for all temperatures above 40° the observations show a decrease in the amount of the reduction *fully equal* to the increase computed from the formula. This result shows that while the formula of Laplace gives the reduction to sea-level with tolerable accuracy when the atmosphere is nearly in a condition of equilibrium, it gives very erroneous results when the atmosphere is greatly disturbed. While the pressure at

Summit remains unchanged, the observed change in the reduction to Sacramento resulting from a change of temperature is 41 per cent less than that computed from the formula; but at all temperatures the observed reduction accords nearly with that computed from the formula when the barometer at Sacramento stands at 29·9 inches.

Reduction of barometer from Summit (elevation 7,017 feet) to Sacramento (elevation 31 feet).

Temp.		22·7.	22·8.	22·9.	23·0.	23·1.	23·2.	23·3.	23·4.	23·5.	23·6.
25°	L	7·057	7·088	7·119	7·150	7·181	7·212	7·243	7·274	7·305	7·336
	O				7·037	7·016	7·000	6·983			
30	L	6·967	6·997	7·028	7·059	7·089	7·120	7·151	7·182	7·212	7·243
	O			6·997	6·989	6·975	6·953	6·936	6·928		
35	L	6·879	6·910	6·940	6·970	7·001	7·031	7·061	7·091	7·122	7·152
	O	6·987	6·976	6·967	6·948	6·930	6·911	6·889	6·867	6·841	
40	L	6·794	6·824	6·854	6·884	6·914	6·944	6·974	7·003	7·033	7·063
	O		6·923	6·919	6·906	6·889	6·870	6·844	6·811	6·787	6·750
45	L	6·711	6·740	6·770	6·799	6·829	6·858	6·888	6·917	6·947	6·977
	O			6·895	6·884	6·851	6·825	6·798	6·766	6·730	6·695
50	L	6·629	6·658	6·688	6·717	6·746	6·775	6·804	6·834	6·863	6·892
	O				6·856	6·810	6·765	6·737	6·703	6·672	6·650
55	L	6·549	6·578	6·607	6·636	6·665	6·694	6·723	6·752	6·781	6·810
	O					6·720	6·698	6·667	6·633	6·597	
60	L	6·472	6·501	6·529	6·558	6·586	6·615	6·643	6·672	6·700	6·729
	O					6·652	6·626	6·606	6·575	6·538	
65	L	6·397	6·425	6·454	6·482	6·510	6·538	6·566	6·594	6·623	6·651
	O						6·586	6·560	6·530	6·506	
70	L	6·323	6·351	6·379	6·406	6·434	6·462	6·490	6·518	6·546	6·574
	O						6·560	6·511	6·487	6·449	
75	L	6·251	6·278	6·306	6·333	6·361	6·389	6·417	6·445	6·472	6·499
	O							6·481	6·438	6·401	
80	L	6·180	6·207	6·234	6·262	6·289	6·316	6·343	6·371	6·398	6·425
	O									6·366	

In order to study this question under a still greater variety of circumstances I selected two elevated stations in Europe, viz: Grand St. Bernard and Colle di Valdobbia. The former station is situated in a pass over the Alps, at an elevation of 2,462 meters above the sea, and the station selected for comparison is Geneva, distant 55 English miles from St. Bernard and elevated 407 metres above the sea. The observations are published in the Bibliothèque Universelle de Genève, and I have employed the observations of three years, viz: 1877, 8 and 9. The mode of reducing the observations was similar to that described on page 10. The results are shown in the table on page 12 which exhibits the reduction computed by the Laplace formula from Delcros' Tables (Smithsonian Tables, series D, page 11), for a range of the barometer from 546 to 573 millimeters, and for a

range of temperature from $-12°$ to $+18°$ centigrade. The same table shows the observed reduction as far as the range of the observations will permit.

Reduction of barometer from Grand St. Bernard (elevation 2,462 meters) to Geneva (elevation 407 meters).

Ther. Cent.		546.	549.	552.	555.	558.	561.	564.	567.	570.	573.
° −12	L	169·44	170·37	171·31	172·24	173·18	174·11	175·05	175·99	176·92	177·84
	O			169·83	170·79						
10	L	167·84	168·77	169·70	170·62	171·55	172·47	173·40	174·33	175·26	176·17
	O	167·02	167·99	168·89	169·64	170·43	171·19				
8	L	166·26	167·18	168·10	169·02	169·94	170·85	171·77	172·69	173·61	174·52
	O	165·94	166·88	167·76	168·60	169·42	170·38	171·36			
6	L	164·71	165·62	166·52	167·43	168·34	169·25	170·16	171·17	171·98	172·88
	O	164·66	165·52	166·37	167·20	167·90	168·69	169·57	170·51		
4	L	163·20	164·10	164·99	165·89	166·79	167·69	168·58	169·48	170·38	171·28
	O	163·04	163·88	164·72	165·55	166·33	167·08	167·84	168·46		
− 2	L	161·70	162·59	163·48	164·37	165·26	166·15	167·04	167·93	168·82	169·71
	O		162·00	162·95	163·90	164·71	165·49	166·27	166·97	167·63	
0	L	160·22	161·10	161·98	162·87	163·75	164·64	165·52	166·41	167·29	168·17
	O		160·40	161·46	162·33	163·18	163·99	164·80	165·61	166·65	
+ 2	L	158·78	159·65	160·53	161·41	162·28	163·16	164·03	164·91	165·78	166·65
	O			159·79	160·85	161·72	162·53	163·37	164·19	164·90	165·57
4	L	157·36	158·23	159·10	159·97	160·83	161·70	162·57	163·44	164·30	165·17
	O				159·43	160·40	161·37	162·12	162·89	163·67	164·57
6	L	155·98	156·84	157·70	158·55	159·41	160·27	161·13	161·99	162·84	163·70
	O					159·77	160·52	161·06	161·80	162·58	163·33
8	L	154·62	155·47	156·32	157·17	158·02	158·87	159·72	160·57	161·42	162·27
	O						159·30	160·03	160·75	161·51	162·17
10	L	153·28	154·11	154·96	155·80	156·64	157·49	158·33	159·18	160·02	160·87
	O						158·00	158·79	159·63	160·38	161·16
12	L	151·96	152·79	153·63	154·46	155·30	156·14	156·97	157·81	158·64	159·48
	O							157·77	158·46	159·14	159·87
14	L	150·67	151·50	152·33	153·15	153·98	154·81	155·64	156·47	157·29	158·12
	O								157·08	157·77	158·50
16	L	149·39	150·21	151·03	151·85	152·67	153·49	154·32	155·14	155·96	156·78
	O								155·31	156·29	157·26
18	L	148·12	148·93	149·75	150·56	151·38	152·19	153·01	153·82	154·63	155·45
	O									154·83	155·70

We see that the observed reduction accords with the computed reduction much better than in either of the preceding cases. The change in the value of the reduction due to a change either of the barometer or thermometer is, however, a little less than that computed from the formula.

The other elevated station selected is the Colle di Valdobbia, situated about 10 English miles south of Monte Rosa, at an elevation of 2,485 meters above the sea, and the station selected for comparison is Alessandria, distant about 70 English miles, and elevated 98 meters above the sea. The observations are

published in Bullettino Meteorologico dell' Osservatorio in Moncalieri, and the years selected for comparison are those of 1877, 8 and 9. The observations were reduced in the manner already described on page 10, and the results are shown in the following table which is arranged in the same manner as the preceding table.

Reduction of barometer from Colle di Valdobbia (elevation 2,485 meters) to Alessandria (elevation 98 meters).

Ther. Cent.		543.	546.	549.	552.	555.	558.	561.	564.	567.	570.	573.
° −10	L	198·34	199·44	200·53	201·63	202·73	203·82	204·92	206·02	207·12	208·21	209·31
	O				197·00							
8	L	196·44	197·53	198·61	199·70	200·79	201·87	202·96	204·05	205·14	206·22	207·31
	O		197·49	197·50	197·50	197·49	197·47					
6	L	194·57	195·65	196·72	197·80	198·88	199·95	201·03	202·11	203·19	204·26	205·34
	O		194·67	195·48	196·07	196·65	197·13					
4	L	192·74	193·81	194·87	195·94	197·00	198·07	199·14	200·20	201·27	202·33	203·40
	O		192·75	193·83	194·68	195·47	196·10	196·41	196·52			
− 2	L	190·94	192·00	193·05	194·11	195·16	196·22	197·28	198·33	199·39	200·44	201·50
	O	190·46	191·47	192·49	193·28	193·93	194·46	194·84	195·13	195·28		
0	L	189·17	190·22	191·26	192·31	193·35	194·40	195·45	196·49	197·54	198·58	199·63
	O		190·85	191·54	192·04	192·53	193·04	193·55	194·01	194·27	194·53	
+ 2	L	187·43	188·47	189·50	190·54	191·58	192·61	193·65	194·69	195·73	196·76	197·80
	O			190·45	190·93	191·46	192·01	192·55	193·06	193·57	194·12	
4	L	185·73	186·76	187·79	188·81	189·84	190·87	191·90	192·93	193·95	194·98	196·01
	O			189·20	189·82	190·27	190·98	191·56	192·06	192·58	193·13	
6	L	184·07	185·09	186·11	187·12	188·14	189·16	190·18	191·20	192·21	193·23	194·25
	O				188·41	189·08	189·68	190·34	190·88	191·37	191·87	
8	L	182·43	183·44	184·45	185·45	186·46	187·47	188·48	189·49	190·49	191·50	192·51
	O					187·69	188·37	189·01	189·66	190·20	190·70	
10	L	180·81	181·81	182·81	183·81	184·81	185·81	186·81	187·81	188·81	189·81	190·81
	O						186·98	187·67	188·37	188·94	189·59	
12	L	179·21	180·20	181·20	182·19	183·18	184·17	185·17	186·16	187·15	188·15	189·14
	O						185·63	186·39	187·04	187·70	188·20	
14	L	177·64	178·62	179·61	180·59	181·58	182·56	183·55	184·53	185·52	186·50	187·49
	O							185·14	185·78	186·41	187·06	
16	L	176·11	177·08	178·05	179·03	180·01	180·98	181·96	182·94	183·92	184·89	185·87
	O							183·87	184·52	185·33	185·82	186·22
18	L	174·60	175·57	176·54	177·50	178·47	179·44	180·41	181·38	182·34	183·31	184·28
	O								184·05	184·21	184·42	184·42
20	L	173·11	174·07	175·03	175·99	176·95	177·91	178·87	179·83	180·79	181·75	182·71
	O									183·19	183·14	183·15

This table shows results quite different from those of the preceding table. While the pressure at the upper station remains unchanged, the observed change in the reduction to the lower station resulting from a change in the temperature of the air-column is 30 per cent less than that computed from the Laplace formula with the constants of Delcros. While the

mean temperature of the air-column remains unchanged, the observed change in the reduction to the lower station resulting from a change of pressure at the upper station, is only one-half of that computed from the formula. Thus we see that the reduction of barometric observations to sea-level follows different laws at different localities. The following table shows a summary of these results for these five mountain stations:

Stations.	Change of reduction depending upon Thermometer.	Barometer.
Mt. Washington,	0·973	+0·142
Pike's Peak,	·675	+ ·195
Summit, Cal.,	·590	— ·866
Grand St. Bernard,	·912	+ ·989
Colle di Valdobbia,	·695	+ ·500
Mean,	·769	+ ·192

Column 1st shows the names of the mountain stations; column 2d shows the average values of the observed change in the reduction to the lower station resulting from a change in the temperature of the air-column, and compared with the change computed from the formula; column 3d shows the average value of the observed change in the reduction resulting from a change of pressure at the upper station, and compared with the computed change.

A comparison of these results shows that the temperature coëfficient employed by Delcros and Guyot is too large; and the observed values of the reduction to sea-level would in most cases be somewhat better represented by assuming a larger value for the coëfficient 18336 meters or 60158·6 English feet adopted by Laplace from the observations of Ramond made more than 75 years ago. It does not seem possible, however, by any change of these coëfficients to modify the Laplace formula so that it may satisfactorily represent the results at all of the preceding stations; or even at a single station for all variations of temperature and pressure.

The Laplace formula assumes that the atmosphere has attained a condition of equilibrium, and in such a case it gives the reduction to sea-level with tolerable accuracy. The average of a long series of observations represents approximately such a condition of equilibrium; but in the daily observations this equilibrium is very much disturbed. The mean between the temperatures at the upper and lower stations does not represent the average temperature of the intermediate column of air; and when the atmosphere is in rapid motion the downward pressure is modified by the earth's rotation in a manner not represented by the Laplace formula. There is no doubt that the formulæ of reduction now employed may be considerably improved; but it does not seem possible that any single

formula with constant coëfficients should provide for the immense variety of conditions which prevail in the neighborhood of mountain stations; and we may be compelled for each mountain region to adopt tables founded upon a direct comparison of observations made at stations of different elevations and not very remote from each other.

I have endeavored to represent by formulæ of a different kind the observed values of the reduction given in the preceding tables. They may all be rudely represented by expressions of the form

$$\text{Reduction} = X - Y\,d\,T + Z\,d\,B,$$

where X represents the value of the reduction for a mean temperature and pressure; Y represents the change in the reduction caused by an increase of 1° in temperature; and Z represents the change caused by an increase of 0·1 inch in the barometer; but this formula is not sufficiently accurate to be of any use. The formula is improved by adding a term representing the variability of the temperature correction. The following expression represents very well the observed values of the reduction for Mt. Washington.

$$\text{Reduction} = 6{\cdot}499 - 0{\cdot}0164\,d\,T + 0{\cdot}0039\,d\,B + 0{\cdot}07 \sin(4°{\cdot}235\,d\,T - 41°{\cdot}175),$$

where dT represents the excess of the temperature of the air column above 28° F., and d B represents the excess of the barometer on Mt. Washington above 23·5 inches. By adding another term representing the variability of the barometric correction the formula may be made to represent the observations still more closely; but this term is so small in amount that it cannot be satisfactorily determined without observations continued for a longer period.

The observed values of the reduction given for Mt. Washington may be condensed into a small table which shall represent these values with differences perhaps no greater than their probable errors. For this purpose I take the mean of all the observed values corresponding to the temperature −10°, and also determine the average correction at that temperature for a change of 0·1 inch in the barometer. I do the same for the temperature −5°, and so on through the table. By applying the proper barometric correction, these averages are all reduced to the barometric height 23·5 inches.

In the following table, column 1st shows the degrees of the thermometer (Fah.) from −10° to + 80°; column 2d shows for each temperature the mean reduction to sea-level when the barometer on Mt. Washington stands at 23·5 inches; and column 3d shows the correction due to a change of 0·1 inch in the

barometer; column 4th was obtained in a similar manner and shows the reduction from Pike's Peak to Denver when the barometer on Pike's Peak stands at 17·6 inches, and column 5th shows the correction due to a change of 0·1 inch in the barometer; column 6th shows the reduction from Summit to Sacramento when the barometer at Summit stands at 23·3 inches, and column 7th shows the correction for 0·1 inch in the barometer, which correction is negative when the pressure increases.

Reduction of barometric observations.

Therm. Fahr't.	Mt. Washington and sea-level. Barometer 23·5 inches.		Pike's Peak and Denver. Barometer 17·6 inches.		Summit and Sacramento. Barometer 23·3 inches.	
	Reduction.	Correction 0·1 inch bar.	Reduction.	Correction 0·1 inch bar.	Reduction.	Correction 0·1 inch bar.
−10°	7·158	·0021	7·600	·0070		
− 5	7·054	·0056	7·541	·0060		
0	6·943	·0061	7·448	·0022		
+ 5	6·831	·0039	7·367	·0022		
10	6·732	·0015	7·290	·0013		
15	6·657	·0032	7·227	·0023		
20	6·586	·0032	7·179	·0108		
25	6·520	·0047	7·112	·0077	6·982	−·0180
30	6·450	·0068	7·055	·0086	6·942	−·0138
35	6·374	·0074	6·993	·0113	6·888	−·0182
40	6·307	·0035	6·929	·0132	6·833	−·0216
45	6·239	·0024	6·858	·0150	6·791	−·0286
50	6·173	·0024	6·786	·0157	6·742	−·0343
55	6·107	·0027	6·725	·0160	6·663	−·0307
60	6·037	·0026	6·716	·0057	6·599	−·0285
65	5·968	·0022			6·558	−·0267
70					6·520	−·0370
75					6·480	−·0400
80					6·432	

The irregularities of these numbers may be diminished by taking the mean of each three consecutive numbers in each of the vertical columns; but I prefer to leave the numbers precisely as they have been derived from the preceding tables.

If the formulæ of reduction to sea-level hitherto employed are admitted to be unsatisfactory for great elevations, it does not seem safe to conclude that they are correct for small elevations. For elevations less than 1000 feet the error of reduction is less palpable than for an elevation of 6000 feet, but it is probable that the error is only proportionally diminished.

Height of the Signal Service stations.

In my 12th paper I gave the results of some computations which indicated considerable errors in the assumed heights of some of the stations of the Signal Service. The publication

in the Annual Report for 1879 of the mean barometric heights for all the stations of the Signal Service without reduction to sea-level, affords materials for a new determination of these heights. The following table shows all the stations of the Signal Service whose elevation above the sea is more than 1000 feet, and for which the mean heights of the barometer are given for a series of years. Column 1st shows the name of the station; columns 2d and 3d the latitude and longitude; column 4th the elevation in feet as assumed by the Signal Service; column 5th the mean height of the barometer for the entire year, as given in the Report for 1879, page 451; column 6th shows the mean temperature of the station; column 7th shows the mean temperature at sea-level under the station, determined in the manner described in my 12th paper; column 8th shows the mean height of the barometer for each station at sea-level. These numbers were determined in the following manner. For all stations whose elevation was less than 1000 feet I took the mean height of the barometer according to the reduction adopted by the Signal Service; and for stations elevated more than 1000 feet I made the reduction according to the elevations as I had previously determined them. I took the mean barometric heights for all the meteorological stations of the Dominion of Canada, so far as they are published in the official Reports. For various additional stations in the vicinity of the United States, I took the barometric heights from Buchan's Memoir on the Mean Pressure of the Atmosphere, in the Transactions of the Royal Society of Edinburgh, vol. xxv. These numbers were all represented as accurately as possible by isobars drawn upon a chart of the United States. This chart is exhibited upon a greatly reduced scale on Plate I. From this chart the most probable mean pressure for each station was derived, and the results are given in column 8th of the table. Column 9th shows the altitude of each station computed from the data here given according to Guyot's Tables; and column 10th shows the altitude computed from Williamson's Tables which are founded upon Plantamour's formula. The height of Pike's Peak was obtained by computing first its elevation above Denver from the observed values of the pressure and temperature at those stations, and adding this result to the height of Denver computed from the data contained in the table for that station.

The height of several of these stations has never been determined by direct measurement so far as I have been informed. If we compare the heights of those stations which have been thus determined, as reported in Gannett's List of Elevations, we find them to accord reasonably well with the results above given as computed from the formula of Laplace. If we take

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the differences between the numbers in columns 4 and 9 for those stations whose heights have been determined by direct measurement, we shall find that the sum of the positive differences is about equal to the sum of the negative differences, which seems to indicate that Guyot's Tables give better results than Williamson's Tables, and that they may be depended upon for heights deduced from the mean of a long series of barometric observations.

Stations of the U. S. Signal Service whose elevation above the sea is more than 1,000 *feet.*

Station.	Lat.	Long.	Elevat'n Sig. Ser.	Mean Barom.	Temperature.		Barom. Sea-lev.	Elevation.	
					Station.	Sea-lev.		Laplace.	Plant'r.
	°	°			°	°			
Pike's Peak	38·8	105·0	14150	17·750	19·2	55·4	30·032	14054	14116
Santa Fé	35·7	106·2	6851	23·265	48·8	58·8	30·023	7011	7029
Mt. Washing'n	44·3	71·3	6285	23·626	25·9	45·5	29·973	6286	6319
Cheyenne	41·2	104·7	6057	24·015	44·8	51·4	30·031	6068	6093
Pioche	38·0	114·4	5778	24·039	54·9	55·9	30·037	6143	6165
Virginia City	45·3	112·0	5480	24·238	41·0	49·6	30·039	5788	5810
Denver	39·7	105·1	5269	24·779	49·3	54·2	30·032	5260	5278
Salt Lake City	41·2	112·0	4362	25·642	52·4	53·3	30·042	4342	4355
Winnemucca	41·0	117·7	4335	25·621	50·2	54·1	30·050	4366	4379
Boise City	43·7	116·1	2877	27·144	52·4	52·4	30·060	2795	2804
North Platte	41·1	100·9	2838	27·057	48·7	51·7	30·029	2841	2851
Dodge City	37·6	100·1	2486	27·381	54·1	56·6	30·033	2549	2557
Bismark	46·8	100·6	1704	28·154	41·0	42·7	30·010	1708	1716
Yankton	42·7	97·5	1275	28·718	45·8	49·5	30·023	1205	1208
Fort Sill	34·7	98·5	1100	28·779	60·6	60·6	30·032	1188	1192
Omaha	41·3	96·0	1077	28·876	49·8	50·8	30·030	1068	1072

In preparing the materials for this article, I have been assisted by Mr. Henry A. Hazen, a graduate of Dartmouth College of the class of 1871; and Mr. Orray T. Sherman, a graduate of Yale College of the class of 1877.

ART. II.—*Coal Dust as an element of danger in Mining;* by Rev. H. C. HOVEY, A.M.

CHEMICAL action is often induced in heaps of slack, such as exist in thick coal workings, and the heat evolved may be enough to cause ignition. The danger is greatly increased when the broken coal is comminuted and floats in the air in the form of dust, which under various conditions may undergo rapid oxidation.

Galloway's experiments show that when the particles are so fine as to pass through the gauze shield of a safety-lamp, an explosion may be caused by their ignition. Bauerman states that in the French collieries, "several fatal explosions have been traced to the firing of coal dust from the flame of a blast,

even in cases where no fire-damp was present in the workings." The influence of coal dust in spreading the effects of gas explosions is one of the subjects of investigation by the royal commission on accidents in mines, now sitting in England.

My object in this article is to lay before the public, by permission of Mr. Edwin Gilpin, Inspector of Mines for Nova Scotia, the results of his investigation into the part played by coal dust in spreading and augmenting the late explosion in the Albion mines.

The seam is well-known as one of the largest in the world, being thirty-seven feet in thickness, and spreading over a large extent of ground. Many million tons of coal have been extracted from the various pits, since work was begun in 1807, and the mining establishment has long been regarded as one of the most complete that could be devised. The pit in which the explosion occurred on the 12th of November, 1880, was nearly 1000 feet deep, and was ventilated as thoroughly as possible by a large Guibal fan, capable of circulating 120,000 cubic feet of air per minute through the ramifications of the mine. Shortly before the accident referred to, I went entirely through the colliery, in company with Mr. Gilpin and the overman, and we remarked the perfection of the ventilation, and the consequent absence of deleterious gases, even in the remotest bords. On the morning of the disaster, the night watchman reported the mine to be free from gas, except in small and harmless quantities. From what source, then, originated the series of explosions, that began within an hour from the time when this report of entire safety was made, and continued at intervals until the mine became a furnace, whose flames could be subdued only by emptying into its burning chambers the waters of an adjacent river? Was there some sudden exudation of gas from the solid coal, or was this explosion due to the firing of coal dust from a safety-lamp or the flame of a blast?

None of the forty-four men who witnessed the beginning of the catastrophe escaped to explain the mystery; those rescued from more distant galleries had but conjectures to offer; and the only facts definitely ascertained were gathered by an exploring party led by Mr. Gilpin, who, shortly after the original explosion, and at the risk of life, descended into the pit and penetrated as far into the workings as the after-damp would allow. The locality where the unfortunate workmen whom they tried to save were known to be was 1200 yards south of the shaft; and the point reached by the party was only about 600 yards in that direction. They found several dead bodies of men and horses, killed in some cases by concussion and in others by the after damp, but none bore the marks of fire, nor was the splintered woodwork of the broken timbers charred;

and the conclusion was plainly justifiable that the flame of the explosion had not extended thus far.

The walls of the galleries had been swept clear of timber, and presented the appearance of having been brushed with a broom. Volumes of coal dust had been driven along by the force of the blast, and lay in waves and drifts on the floor of the levels, into which the party sank to their knees. It was found that clouds of the finer particles had been carried to the shaft and beyond it into the main north level, where a secondary explosion had taken place, demolishing the "lamp cabin," burning the horses between the shaft and the cabin, and fatally burning the man whose business it was to clean and distribute safety lamps to the miners.

Secondary explosions caused by extracted or generated gas are nearly always in the vicinity of the first one; but here is a case where the second was half a mile from the first, with an intervening space of at least a quarter of a mile known to have been free from flame, and presumed to be free from gas, because men were in it with lamps which showed no indications of its presence.

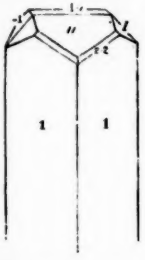
Water was continually trickling down the shaft, and the levels for some distance around were very wet, hence the dust, as soon as it touched the wet walls would be made innocuous; but the fine, dry particles of carbon that were driven on into the lamp cabin were ready for ignition. It had been the custom for years to keep an oil lamp burning openly here, as the proximity of the shaft and consequent purity of the air made the practice, under ordinary circumstances, perfectly safe. But on this occasion it seems to be certain that the ignition of the coal dust caused a second explosion; and it is probable that the same agency was efficient in producing, or at least augmenting, the subsequent explosions that made it necessary to flood the whole mine. It was as if the wadding of a gun were composed of an inflammable material, which on firing the charge doubled its effect. It should also be noted that, as a rule, the Albion mines were very dry, except in portions nearest the shaft, and the accumulation of dust was very great.

I have only aimed to publish the facts, hoping that some one else may explain on chemical principles the remarkable exhibition of force, as well as of heat, accompanying the ignition of an impalpable and homogeneous powder. Professor Abel's experiments have shown that even finely powdered slate will spread the flame of gas explosions; and it is alleged that there have been frequent explosions of flour dust in large mills in some of the western States. In view of these facts the matter, though confessedly not well understood, is worthy of attention from scientific men, and perhaps none the less so for that very reason.

ART. III.—*Notes on Mineral Localities in North Carolina;* by WM. EARL HIDDEN.

MONAZITE *from Milholland's Mill, Alexander Co.*—In August last (1880) I obtained at this locality some very beautiful crystals of geniculated rutile, which had been found there loose in the soil. Permission having been obtained to work the property I succeeded on the first day's working* in finding these rutiles *in situ*. In connection with the work I "panned down" some of the loose vein material, and in this manner the monazite crystals were first discovered. There is every probability that if the work at the locality is continued the monazite will be found in place in the vein. The rock is a garnetiferous mica schist. The vein (or pocket as it may yet prove to be) is about a foot wide at its widest and thus far has been uncovered only about eight feet. My operations were necessarily limited, and the locality merits further examination. The associated minerals are *muscovite* (?), emerald green through the prism, very abundant and making up 95 per cent of the vein, crystals thin hexagonal tables and unusually perfect; *quartz crystals*, elongated prisms commonly doubly terminated and in parallel groupings, often cavernous; *rutile*, finely geniculated and splendent; some decomposed pyrites with cavities containing native sulphur; a few pseudomorphs of *limonite* after siderite, in rhombohedrons having the basal and scalenohedral planes.

In concentrating by "panning," say 15 lbs. of the loose vein material, many hundred minute crystals of monazite would be found, perhaps only a half a dozen of which would exceed $\frac{1}{20}$th inch in diameter; rarely, crystals were found of $\frac{1}{4}$th inch in length. Under the microscope, the majority of the minute monazite crystals are seen to be perfectly transparent and of a topaz color. The planes are very highly polished and lustrous. The crystals are uniformly long prismatic with modified terminations, the prism having the shape of an acute rhomboid, thus differing from those previously figured. The adjoining figure represents the common form with what are supposed to be the proper symbols of the planes. One of the monazites partly enclosed a crystal of mica, which fact would point conclusively to its formation in the vein and also to its later formation.



* The soils of this region are the result of decomposition and disintegration on the spot; it is consequently an easy task to discover the source of minerals found on the surface.

The monazite of this locality, as regards occurrence and form, is essentially the *turnerite* of Levy, which has been shown to be identical with monazite, as was long ago suggested by Prof. J. D. Dana. The mode of occurrence and the associated minerals are nearly identical with the Tavetsch, Switzerland, locality; the titanic acid here taking the form of rutile instead of octahedrite. An analysis by Dr. J. Lawrence Smith is now under way, and the crystallography and general physical characters of the mineral will be described by Dr. E. S. Dana.

*Other localities for monazite.**—In Burke County, monazite is very abundant, particularly at J. C. Mill's gold mine in the Brindletown district. I obtained over fifty pounds of gravel washings from this mine that afforded sixty per cent of monazite. Fourteen ounces of chemically pure monazite were obtained here by sifting old "tailings" and picking out the largest crystals; these were sent to Mr. T. A. Edison, who desired the mineral for the thorina which it was supposed to contain.

The crystals are usually well formed and vary considerably in habit. Figs. 446 and 448, Dana, are common; they are usually very small, though some were found here of $\frac{1}{4}$th inch in diameter. The color is light brown. The common occurrence of this mineral in the gold gravels of North Carolina is worthy of note. I believe that pannings from any of the streams where the local rocks are mica schists would bring it to light. In the auriferous gravels of McDowel, Rutherford, Burke and Polk Counties, N. C., it was noticed in every "panning."

In Mitchell County, at the Deake mica mine, I found well formed crystals of monazite *in situ* in mica schist. They were of uncommon size. One measured $1\frac{1}{2}$ inches long by $\frac{3}{4}$ inch in width, and was one of a group. Half a pound of crystals were obtained in all. They were partly coated with autunite, and were intimately associated with uraninite, gummite, garnet, etc. The characteristic perfect basal cleavage was commonly observed at this locality. In Yancey County, at the Ray mica mine on Hurricane Mountain, I found monazite in white orthoclase. The crystals were very fine, and complex in form; specific gravity 5·243. Dr. F. A. Genth has been at work for some years on the monazite of North Carolina and has separated over a pound of the oxalates of the rare earths of the cerium group from it. We shall await with interest the publication of his results.

URANINITE (pitchblende) occurs at the Deake, Lewis and Flat Rock mica mines in Mitchell County. Pure and unaltered masses of several pounds weight have been found. Cubes and cubo-octahedrons imbedded in feldspar were obtained at the Deake Mine with a thin coating of uranotil or gummite. Some

* Geol. N. Car., Kerr, 1880, p. 84.

of the uraninite masses had a submetallic luster, quite like magnetite, and much of it was devoid of any pitchy appearance. *Gummite*,* *uranotil* and *uranochre*, occur at the above mines in considerable abundance; the three minerals are so intimately associated as to be inseparable, one specimen usually embraces them all. Pseudomorphs (cubes and octahedrons) after uraninite are quite common. A mass weighing six pounds six ounces, the largest yet discovered there, was found lately in the Flat Rock mine, which is partly unaltered uraninite. According to Dr. Genth,† this North Carolina gummite is a mixture of uranic hydrate, uranotil, lead-uranate and barium-uranate. Some of this North Carolina gummite is very beautiful; it varies in the same specimen from a bright lemon-yellow to deep orange-red and often has a core of velvet-black uraninite.

ÆSCHYNITE (?).—A mineral much resembling this species occurs in deeply striated prisms embedded in feldspar at Ray's mica mine. It is associated with apatite and beryl. It has not been analyzed. The crystals are large and well formed. Some groups of the crystals weigh a pound.

SAMARSKITE.—Another locality of this mineral has lately been discovered in Mitchell County. It can now be obtained in masses of many pounds weight. Hundreds of pounds are now awaiting purchasers. At the new deposit there is found associated with it a light brown, resinous-looking mineral of high specific gravity which may be massive hatchettolite, or a new species.

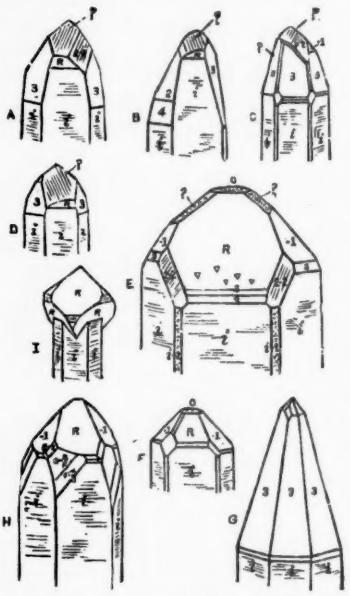
QUARTZ CRYSTALS *from Alexander County*.‡—Some interesting quartz crystals, found in Alexander County, are represented in the following figures. Among them, figures A, B, C and D, are examples of crystals terminated solely by planes in the 2-2 zone, which feature, as far as the writer can gather from the literature on the species, is new. Only in the counties of Iredell, Catawba, Alexander and Burke in North Carolina, and at Cumberland, R. I., have I found crystals having this interesting form. The series of planes *above* 2-2 are mostly rounded, but commonly have a good polish. They are invariably striated parallel to the edge of $2\text{-}2/i$. Right and left-handed crystals are found. The crystal shown in fig. C is of interest since the edge between 3 and 3 is replaced by a plane, and since it has the dihexagonal prism $i\text{-}2$. Special attention is called to the *basal* truncation, fig. E, and to the plane between R and R in the $-\frac{1}{2}$ zone; also to certain inverted (depressed) triangular markings like those on crystals

* Locality discovered by Prof. Kerr in 1877; see this Journal, xiv, 496.

† Geol. N. C., Kerr, 1880, page 34; also American Chemical Journal, i, 87, 1879.

‡ Geol. N. C., Kerr, 1880, page 87.

of diamond. The basal truncation and the (new ?) plane in the $-\frac{1}{2}$ zone occur usually rough, though in two instances they were well polished planes. Fig. F has the dihexagonal pyramid in the i-2 zone. Fig. G represents a crystal almost wholly terminated by the rhombohedron 3. This plane is very common and largely developed on the Alexander County crystals. A fine example of this rare form is in the cabinet of Mr. J. A. Stephenson of Statesville, N. C. Fig. H shows a crystal having the planes 2-2, $3.\frac{3}{2}$,* and $4\text{-}\frac{4}{3}$* beveling every prismatic face at its intersection with R and -1. It also has other interesting rare planes. This crystal was perfectly pellucid, had a beautiful yellow tint and all its planes highly polished. Fig. I illustrates a form not uncommon in North Carolina. Often the cap or terminal crystal is strongly in contrast with the prism in color and transparency. Large groups are often found showing this second formation in parallel position.



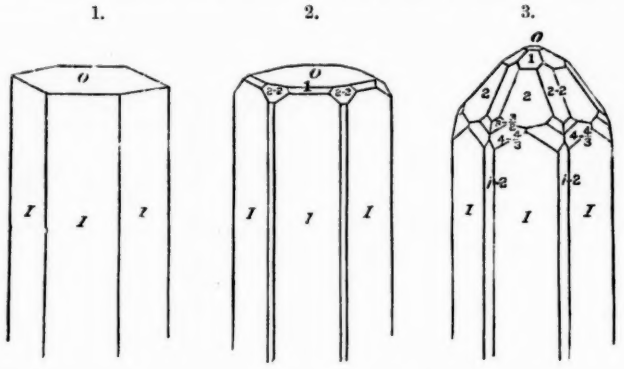
All the figures were drawn directly from the crystals and are of natural size: the determinations of the planes were made with an improvised goniometer and my lettering therefore may be only approximately correct.

BERYLS *from Alexander County.*†—Figs. 1 and 3 represent the extremes in form of these beryls. The crystal, from which fig. 3 was drawn, was at first mistaken for quartz. It was quite small, clear, had both ends terminated and with only a slight tint of green apparent. A crystal of this type but of more interest was collected by Mr. Stephenson from this same locality. It was terminated almost wholly by the planes $3\text{-}\frac{3}{2}$ and $4\text{-}\frac{4}{3}$. Fig. 2 is the most common form at the locality formerly known as the "Warren farm." They have been found there loose in the soil, of a light chrome green color, having prisms of six and twelve sides, and with polished terminations; the prismatic faces have a characteristic feature of being striated horizontally as if having been scratched with a

* More probably $6\text{-}\frac{6}{5}$ and $8\text{-}\frac{8}{7}$.

† Geol. N. C., Kerr, 1880, page 88.

very coarse file. As yet they have not been found of sufficient depth of color and transparency for use as gems, but are quite unsurpassed by any beryls heretofore found in the United States. Those occurring in the soil have weathered out of cavities in the rock where they were formed. They were never imbedded, as some late work at the locality has well proven.



Heretofore the only dependence for them has been the soil; now a narrow vein bearing them has been found by the writer and a shaft twenty-four feet deep has been sunk on it. It was the beautiful color of these beryls that prompted the work that so unexpectedly yielded the new variety of spodumene.* There are good indications of yet finding here the true beryl emerald, and it is with this end in view, coupled with the mining of the new spodumene emerald, that the writer is now at work in this State.

PLATINUM.—A diligent search for traces of this metal for five months in the auriferous regions of the Southern States in the interest of Mr. T. A. Edison resulted in finding *no traces of its existence.* The five reported localities in this State (N. C.) were carefully examined without success.

To the generous publicity that the late Professor Humphreys and Mr. J. Adlai Stephenson have given to their mineral researches in North Carolina, and to the sight of some of the many beautiful specimens they have sent north, the writer owes the impelling motive of his going to that State and the knowledge which has enabled him to succeed in his explorations.

Stony Point, N. C., Nov. 20th, 1880.

* This Journal, vol. xxi, Feb., 1881.

ART. IV.—*Variation in Length of a Zinc Bar at the same Temperature;* by Gen. C. B. COMSTOCK.

[Communicated by Authority of the Chief of Engineers, U. S. A.]

THE U. S. Lake Survey possesses a steel normal meter designated as (R. 1876), and a meter designated as (M. T. 1876), composed of a bar of steel and one of zinc so arranged as to form a metallic thermometer. Both were made by Repsold. It has also a base-measuring apparatus by Repsold of which the essential parts are tubes of cast iron four meters long, each containing in its interior a steel and a zinc bar arranged to form a metallic thermometer. Irregularities in the results of comparisons of two bars in the same tube, which were very marked functions of the temperature changes, led to an examination of the question whether a zinc bar has always the same length at a given temperature. The results seem to show conclusively that it has not. I have not met elsewhere with comparisons establishing such a change; if they have been made, these comparisons may give additional data. Mr. E. S. Wheeler, who made the larger part of the comparisons, first called my attention to the indications of a set shown by the ordinary comparisons.

As to the accuracy of the comparisons it may be said that they were made with an apparatus constructed by Repsold, in a comparing-room lined on all sides with saw-dust; that this lining reduces the diurnal temperature fluctuation to 0°·3 F.; that the changes in the external mean daily temperature rarely produce a change in the comparing-box exceeding 2°·5 F. per day; that but two visits were made to the comparing-room in a day; that the probable error in the result of one visit and comparison of two steel bars one meter long is about $1^{\mu}\cdot9$ (microns), and that artificial heat is not used. Temperatures were determined by thermometers whose probable errors do not exceed 0°·05 F., one lying on each meter.

In the experiments with the zinc bar of (M. T. 1876), this meter was alternately heated and cooled, and after each heating or cooling was compared with (R. 1876), which remained in the comparing-box during the twenty days covered by the experiments, its temperature varying in that time only about 3° F. In heating (M. T. 1876) it was taken from the comparing-room at a temperature of about 36° F. to another room, and kept at a temperature between 70° F. and 80° F. for twenty hours or more, then it was replaced in the comparing-box, where it cooled slowly to the temperature of the comparing-

room in about twenty-four hours. Comparisons with (R. 1876) were made during this period and for three days or more afterward. (M. T. 1876) was cooled from the temperature of the comparing-room to about −3° F. by being placed for about twenty hours in a tin case surrounded by a mixture of snow and salt. Then it was placed in the comparing-box, allowed to approach the temperature of the comparing-room, and comparisons were made as before with (R. 1876). Temperatures of greatest cooling and heating were taken with maximum and minimum thermometers.

From comparisons at both high and low temperatures, the relative lengths and expansions of (R. 1876), (M. T. 1876) steel bar, and (M. T. 1876) zinc bar, are approximately known. They are, (R. 1876) = steel bar of (M. T. 1876)+$45^{\mu}\cdot7-0^{\mu}\cdot39\ (t-32^{\circ})$; zinc bar of (M. T. 1876)=steel bar of

$$(\text{M. T. 1876})+267^{\mu}\cdot5+10^{\mu}\cdot15\ (t-32),$$

in which expressions t is the temperature in Fahrenheit degrees. The residual errors have been computed with these values. As the temperature-range was small during the comparisons given in the table, slight errors in expansion values will have little influence on the variations in the residuals.

In the following tables, the first column gives the date of comparison; the second and third give the temperatures of mercurial thermometers lying on the two meters; the fourth gives the residual errors of the comparisons of (R. 1876) and steel bar of (M. T. 1876) in the sense computed minus observed; and the fifth gives the residual errors of the comparisons of (R. 1876) and the zinc bar of (M. T. 1876). The section of these bars is 13^{mm} by 27^{mm}. In computing residuals the temperature of (M. T. 1876) is taken as the temperature of both meters.

From the residuals, considering only those comparisons forty-eight hours or more after the heating or cooling had ended, it is seen that the zinc bar of (M. T. 1876), when it is heated for twenty hours or more to a temperature of 70° F. and then is allowed to cool to its original temperature, 36° F., has a certain length; that if it is then cooled for twenty hours to a temperature of −3° F., and afterwards is allowed to return gradually to its original temperature of 36° F., it will have a certain other length; and that these lengths at the same temperature may differ by fifteen microns. Both (R. 1876) and the bars of (M. T. 1876) were freely exposed to the air inside the comparing-box. If any large portion of the apparent change in length of the zinc bar of (M. T. 1876) was due to temperature errors, the residuals of the steel bars should show it at least in part.

***Tables giving dates, temperatures and residuals of comparisons of* (R. 1876) *and* (M. T. 1876) *made after periods of heating and cooling of* (M. T. 1876.) Preliminary reduction.**

1. (M. T. 1876) heated, Feb. 7 to Feb. 14, 10.50 A. M. and kept at temperatures between 70° and 80° F.

Date of Comparison.	Temperature of (R. 1876.)	Temperature of (M. T. '76.)	(R. 1876)—(M. T. 1876)$_s$, computed, minus (R. 1876)—(M. T. 1876)$_s$, observed.	(M. T. 1876)$_x$—(M. T. 1876)$_s$, computed, minus (M. T. 1876)$_x$—(M. T. 1876)$_s$, observed.
1881.			μ	μ
Feb. 16, 9.14 A. M.	37°02 F.	36°91 F.	−0·4	−18·6
" 16, 8.19 P. M.	36·92	36·81	−1·7	−17·8
" 17, 9.12 A. M.	36·52	36·41	−0·4	−17·6
" 17, 7.58 P. M.	36·32	36·21	−0·4	−15·8
" 18, 9.35 A. M.	36·12	36·21	+0·3	−14·3
" 18, 8.49 P. M.	36·32	36·21	+1·2	−17·5
" 19, 9.25 A. M.	36·37	36·31	+3·0	−16·4
" 19, 8.05 P. M.	36·42	36·41	+0·5	−14·4
" 20, 10.38 A. M.	36·32	36·21	+1·7	−15·6
" 20, 8.37 P. M.	36·42	36·41	+1·3	−12·7
" 21, 9.56 A. M.	36·52	36·41	+3·2	−14·2
" 21, 8.09 P. M.	36·62	36·61	+1·0	−13·9
" 22, 10.12 A. M.	36·72	36·71	−1·2	−13·7
" 22, 8.44 P. M.	37·12	37·21	+0·9	−12·3
" 23, 9.22 A. M.	37·32	37·26	−0·9	−15·3
" 23, 7.35 P. M.	37·07	37·01	+1·1	−14 8
" 24, 9.17 A. M.	36·52	36·51	+1·4	−13·8

2. (M. T. 1876) cooled for 23 hours: Feb. 24, 10.00 A. M. to Feb. 25, 9.30 A. M. and kept at temperatures between −1° and −6° F.

			μ	μ
Feb. 25, 7.22 P. M.	35°52	35°42	+2·1	+2·4
" 26, 9.03 A. M.	34·91	34·82	+2·4	−0·5
" 26, 9.38 P. M.	34·91	34·82	+4·0	+1·6
" 27, 10.22 A. M.	35·31	35·22	+0·4	+0·3
" 27, 7.43 P. M.	35·91	35·81	−0·6	+1·7

3. (M. T. 1876) heated for 22 hours: Feb. 28, 11.30 A. M. to Mar. 1, 9.10 A. M., being kept at temperatures between 70° and 80° F.

			μ	μ
Mar. 2, 9.11 A. M.	37°02	36°96	0·0	−15·8
" 2, 9.04 P. M.	36·72	36·61	+0·3	−15·3
" 3, 9.07 A. M.	36·32	36·21	−0·2	−16·0
" 3, 8.51 P. M.	36·32	36·21	0·0	−15·7
" 4, 9.09 A. M.	36·32	36·21	−2·4	−14·3

4. (M. T. 1876) cooled for 24 hours: Mar. 3, 9.30 A. M. to Mar. 4, 9.30 A. M., being kept at temperatures between −2° and −5° F.

			μ	μ
Mar. 5, 8.58 P. M.	36°72	36°61	+2·6	+6·6
" 6, 9.50 A. M.	36·82	36·71	+2·2	+6·4
" 6, 8.04 P. M.	37·22	37·16	+1·1	+6·0
" 7, 8.52 A. M.	37·32	37·21	+1·4	+5·1
" 7, 7.56 P. M.	37·58	37·51	+2·8	+5·3
" 8, 9.03 A. M.	37·88	37·81	+3·0	+5·3

$(M.\ T.\ 1876)_s$ denotes the steel bar of (M. T. 1876) and $(M.\ T.\ 1876)_z$, the zinc bar μ is the symbol for micron or thousandth of a millimeter.

The tubes of the Repsold base-apparatus have already been spoken of. A similar experiment was tried with these tubes.

The zinc bars of tube No. 1 and of tube No. 2, as well as their steel bars, were first compared with each other at about 41° F.; then tube 1 was heated for twenty-four hours to a temperature between 70° and 80°, and after the heating the two zinc and the two steel bars were again compared. The relative lengths and expansions of the two steel and of the two zinc bars are given approximately by

$$S'_1 = S'_2 + 1518^{\mu}\cdot 8 - 0^{\mu}\cdot 06t,$$
$$Z'_1 = Z'_2 + 210^{\mu}\cdot 6 - 0^{\mu}\cdot 44t,$$

where t is the temperature of the comparison in Fahrenheit degrees. The lengths designated by S'_1, S'_2, Z'_1, Z'_2, are each very nearly four meters, but are not the lengths used in base measurement. The former are in the neutral axes of the bars and have been used to avoid any question of lateral flexure. Temperatures were observed with three well determined thermometers in the interior of each tube.

In the following table it is assumed that the observed mercurial temperatures are the true temperatures of the bars. The absolute expansions of the bars are known, and with them the observed difference of length of the two bars is reduced to what it would have been if the two bars under comparison had had the same temperature. This is called the observed difference of length of the two bars. Subtracting it from the difference of lengths of the two bars at that temperature as computed from the equations given above, the residuals result. When positive, they indicate that the observed difference of length of the two bars was algebraically too small.

The first column gives the date of the comparison; the second and third, the mercurial temperatures of tube 1 and tube 2; the fourth, the residuals of the steel bars or $S'_1 - S'_2$ computed, minus $S'_1 - S'_2$ observed; the fifth, the residuals for the zinc bars or $Z'_1 - Z'_2$ computed, minus $Z'_1 - Z'_2$ observed.

PRELIMINARY REDUCTION.

Date.	t_1.	t_2.	$S'_1-S'_2$ residuals.	$Z'_1-Z'_2$ residuals.
1881.			μ	μ
Mar. 14, 9.40 A. M.	39°·74 F.	39°·82 F.	−1·0	−2·3
" 15, 9.39 P. M.	40·58	40·67	−3·8	−5·2
" 16, 3·36 P. M.	41·79	41·80	−8·9	−2·5
" 17, 9.27 A. M.	41·90	41·90	−9·7	−2·4
Tube 1 from Mar. 17, 9.30 A. M. to Mar. 18, 9.15 A. M., was kept at a temperature between 70° and 80° F.				
			μ	μ
Mar. 18, 8.15 P. M.	46°·51	45°·12	−10·1	−58·9
" 19, 9.44 A. M.	44·25	43·69	− 8·4	−46·8
" 19, 2.32 P. M.	44·02	43·52	+ 0·9	−38·8
" 19, 8.08 P. M.	43·88	43·50	+ 2·7	−42·1
" 20, 9.39 A. M.	43·66	43·37	+ 4·6	−33·5
" 20, 8.35 P. M.	43·70	43·45	− 6·4	−38·8
" 21, 10.23 A. M.	43·47	43·33	+ 3·5	−35·3
" 21, 8.17 P. M.	43·51	43·32	+ 1·1	−33·4
" 22, 9.12 A. M.	43·33	43·12	+ 2·6	−28·8
" 22, 8.43 P. M.	43·03	42·90	− 4·9	−26·4
" 23, 9.18 A. M.	42·76	42·59	− 0·6	−29·7

An examination of the residuals shows that the mean residual of $S'_1-S'_2$ before heating was $-5^{\mu}\cdot8$, and allowing forty-eight hours to cool, that the mean residual from $9^h\ 39^m$ A. M., March 20, to $9^h\ 18^m$ A. M., March 23, was $0^{\mu}\cdot0$, differing $5^{\mu}\cdot8$ from the previous value, a quantity too small, in view of the very large residuals before heating, to indicate a change in $S'_1-S'_2$. But the mean residual of $Z'_1-Z'_2$ before heating was $-3^{\mu}\cdot1$, and after heating, between March 20, A. M. and March 23, was $-32^{\mu}\cdot2$, a change of 29^{μ}.

It seems, then, that the heating from 41° F. to 75° F., and subsequent cooling to 43° F., increased the length of the four-meter zinc bar about 29^{μ}. This would give a change of 7^{μ} per meter for a temperature change of 30°, or about half the change found for the zinc bar of the meter (M. T. 1876) for a temperature change from −3° to +75°.

Sufficient data have not yet been obtained to determine the time required for a zinc bar to lose this probably temporary change of length. In the case of glass thermometers it is known that sub-permanent changes of form lasting for many weeks occur on heating them.

The question at once occurs, whether bars of other metals may have sensibly differing lengths at the same temperature.

U. S. Lake Survey Office, Detroit, Mich., April 30, 1881.

Art. V.—*Restoration of* Dinoceras mirabile; by Professor O. C. Marsh. With Plate II.

The order of extinct gigantic mammals discovered by the writer in 1870, in the middle Eocene of Wyoming, and named *Dinocerata*, has now been investigated, and all the more important characters of the skeleton carefully determined. In this peculiar group of Ungulates, there are three well-marked genera: *Dinoceras* Marsh, the type genus, *Tinoceras* Marsh, and *Uintatherium* Leidy. These will be fully described by the writer in an illustrated monograph now nearly ready for publication. This memoir will be based upon the remains of more than one hundred and fifty distinct individuals of this order, now deposited in the Museum of Yale College.

The type species of the *Dinocerata* is *Dinoceras mirabile* Marsh, and especial pains have been taken to work out the osteology of this animal, as a key to the structure of the group. Almost every bone in the skeleton is now known by various specimens, and this affords ample material for a restoration which will represent very nearly the osseous framework of the animal when alive. Such a restoration has been attempted for the memoir in preparation, and in the present article a much reduced figure of this is given (Plate II), which shows the general proportions of the type species.

Among the points of special interest suggested by the restoration of *Dinoceras* here presented are the following:

(1.) *The absence of a proboscis.* There is no evidence in the skull of the existence of such an organ, and the proportions of the neck and fore limbs certainly rendered its presence unnecessary.

(2.) *The "horn-cores" of the skull.* An examination of a large number of these, from individuals of various ages, indicates that the posterior pair, on the parietals, were sheathed with thickened integument, which may have developed into true horn, as in the Pronghorn (*Antilocapra Americana*). The surface of the osseous protuberances is very similar in both cases. The pair of elevations on the maxillaries are equally rugose, and bear evidence of a similar covering. The small tubercles on the nasals are usually smoother, and were probably without horn-like sheathing. The three pairs of elevations are present in both sexes, but are proportionally smaller in the females.

(3.) *The canine tusks*, also, are common to both sexes, but those of the males only are large and powerful.

(4.) *The dependant processes of the lower jaw* correspond in size with the canine tusks, and are evidently adapted for their protection. In the females, these processes are but slightly developed.

(5.) *The sternum* is composed of flat horizontal segments, not compressed and vertical, as in Perissodactyls.

The material now available for a restoration of *Tinoceras grande* Marsh, is sufficient to show that this animal was similar in general proportions to *Dinoceras mirabile*, but of much larger size. The few specimens that can at present be referred to *Uintatherium* leave many points in its structure undecided. The type specimen of this genus is from a lower horizon than that of either *Dinoceras* or *Tinoceras;* and the evidence now at hand seems to indicate that *Uintatherium* is the oldest and most generalized form of the *Dinocerata.* One specimen in the Yale Museum from near the original locality, and agreeing, so far as the comparison can be made, with the type, has four lower premolars. This character will serve to distinguish *Uintatherium* from *Dinoceras*, to which it has various points of resemblance. *Tinoceras* is from a horizon higher than *Dinoceras*, and is much the most specialized genus of the group.

Yale College, New Haven, June 14th, 1881.

ART. VI.—*On the Torbanite or "Kerosene Shale" of New South Wales;* by A. LIVERSIDGE.*

The so-called "kerosene shale" does not differ very widely from cannel coal and torbanite. Like cannel coal, it usually appears to occur with ordinary coal in the form of lenticular deposits. Like cannel coal also, when of good quality it burns readily without melting, and emits a luminous smoky flame. When heated in a tube it neither decrepitates nor fuses, but a mixture of gaseous and liquid hydro-carbons distils over.

In color it varies from a brown-black, at times with a greenish shade, to full black. The luster varies from resinous to dull. When struck it emits a dull wooden sound. The powder is light brown to gray; the streak shining.

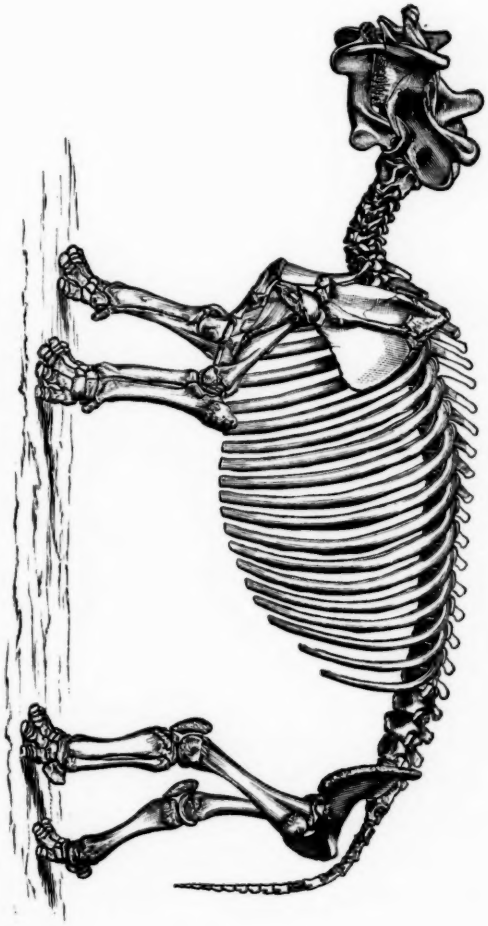
Professor Silliman proposed the name of *Wollongongite* for the mineral; but this has not come into general use, neither is it an appropriate name, since the specimen sent to him was not from Wollongong, but from Hartley.

Analyses afforded:—1, 2, 3, From Joadja Creek, color black, brownish, sp. gr. 1·103, 1·054 and 1·229; 4, From Murrusundi, dark-gray, but with white clayey specks.

Loss at 100° C.	1·160	·440	·040	1·165
Volatile hydro-carbons	73·364	83·861	82·123	71·882
Fixed carbon	15·765	8·035	7·160	6·467
Ash	9·175	7·075	10·340	19·936
Sulphur	·536	·589	·337	·549

A specimen from the Hartley seam, where most free from mineral matter, having sp. gr. 1·052, afforded: Moisture and volatile hydro-carbons 82·24, fixed carbon 4·97, ash 12·79=100. An ultimate analysis of the same, dried at 100° C., gave: Carbon 69·484, hydrogen 11·370, oxygen, nitrogen, and sulphur 6·356, ash 12·790 =100.

* Abstract from paper in Proc. Roy. Soc. N. S. Wales, Dec., 1880.



Restoration of DINOCERAS MIRABILE, Marsh; one twenty-fifth natural size.

Art. VII.—*Meteorological Researches, Part II. Cyclones, Tornadoes and Waterspouts;* by Wm. Ferrel.*

[Abstract, published by permission of Carlile P. Patterson, Superintendent of the United States Coast and Geodetic Survey.]

If all parts of the atmosphere had the same temperature and the same hygrometric state it would remain in a state of static equilibrium. The principal circumstance which disturbs this equilibrium is the difference of temperature between the equatorial and polar regions. This gives rise to an interchanging motion of the air, toward the equator below and from it above, and if it were not for the effect of the earth's rotation on its axis this interchanging motion would be at all places in the direction of the meridian, and would be continually accelerated in its initial motions, until the friction arising from these motions would exactly equal the force producing them, after which the motions of any one place would be constant, but of course different at different places. The now well-known effect of the earth's rotation is to give rise to a deflecting force to the right of the direction of the moving body in the northern hemisphere and the contrary in the southern, whatever may be the direction of motion. Hence the air in moving above toward the poles, is deflected toward the east and in moving toward the equator below, toward the west, so that the tendency is for the air to assume an eastward motion in the middle and higher latitudes, and a westward motion nearer the equator. These latter motions combined with the interchanging motions between the equatorial and polar regions give rise to what are called the general motions of the atmosphere, depending upon the difference of temperature between these regions and independent of local disturbances of temperature.

The amount of eastward motion depends upon the amount of friction, and must be such that the friction at the earth's surface is equal to the force causing this component of motion, and the same with regard to the westward motions. According to well established principles of mechanics, there cannot arise any force from the effect of the earth's rotation, which by means of friction would tend to either increase or decrease the earth's rotation, and hence the eastward and westward components of motion must be so adjusted that the sum of all the moments of force acting upon the earth through friction and tending to affect its rotation, must be equal 0, and hence, as there are eastward components of motion in the higher latitude, there must necessarily be westward ones nearer the equator. The

* Coast and Geodetic Survey Report for 1878. Appendix 10.

eastward motions in the higher latitudes increase with increase of altitude, but nearer the equator the westward motions decrease with increase of altitude and at a certain altitude vanish and become eastward motions.

The deflecting force depending upon the earth's rotation is such that if the air on the parallel of 45° has a velocity of 54 miles per hour, it gives rise to a gradient of pressure, increasing to the right of the direction of motions in the northern hemisphere, and the contrary in the southern, of 0·1 inch of mercury in the distance of one degree of a great circle of the earth. This force, and consequently the gradient, is as the velocity and the sine of the latitude, and hence it is a maximum at the pole and decreases toward and vanishes at the equator. The eastward motion, therefore, in the middle and higher latitudes gives rise to a gradient of pressure increasing *toward* the equator, and the westward motion between the tropics and the equator to a gradient of pressure increasing in a direction *from* the equator, and hence there must be a belt of higher pressure all around the globe, having its maximum at the latitude of 30° or 35°, where the dividing line is between the eastward and westward motions. The pressure diminishes from this maximum toward the poles, so that the pressure at the poles, especially the south pole, is less than at the equator. As the southern hemisphere is mostly covered by the ocean, on which the friction is much less than on land, the eastward velocities in the middle and lower latitudes of this hemisphere in their normal state, amount to almost a gale entirely around the globe, and these give rise to a very steep gradient there, and a great barometric depression at the south pole.

The regularity of the general motions of the atmosphere and of the gradients depending upon them, is very much interfered with by irregularities in the distribution of the earth's temperature arising from ocean currents, and from irregularities of the earth's surface, comprising both sea and land with its mountain ranges. This part of the subject was treated in Part I, of these researches, but some knowledge of the principles contained in this part of the subject and of the results is necessary to understand the theory of cyclones, tornadoes, etc.

Cyclones.—Cyclones arise from more local disturbances of temperature. On account of the want of homogeneity of the earth's surface and of the hygrometric state of the atmosphere, the amount of heat received and radiated by the earth's surface and the atmosphere, is very different in different localities. Where more heat is received than radiated, the temperature must continue to rise until the loss of heat by radiation and other means exactly equals the amount received, and hence there cannot be uniformity of temperature even on the same

latitudes, and there must be a great many local irregularities in the distribution of temperature independent of the great general disturbance of the equality of temperature between the equatorial and polar regions. These must give rise to corresponding motions of the atmosphere which are superadded to those of the general motions. If in the unequal distribution of temperature it should happen, as it must frequently, that there is a somewhat circular area with higher temperature in the interior and with temperature gradients increasing somewhat regularly on all sides from the center outward, we should have, at least approximately, the initial condition of a cyclone. There would be a motion of the air from all sides toward the central part of the warmer and more rare air in the interior, a very slow rising up of the air in this part and a flowing out of the air above; that is, there would be an interchanging motion between the colder and warmer parts of the air, just as in the case of the general motions of the atmosphere there is between the equatorial and polar regions, except that in the one case the flow is toward the central part below and from it above, while in the other it is the reverse. Any limited portion of the earth's surface of not very great extent, may be regarded as a plane, and this by virtue of the earth's rotation, has a gyratory motion around its center, equal to that of the earth's rotation multiplied into the sine of the latitude of this center. Hence, as in the case of the general motions of the earth, this interchanging motion between the central and exterior part of the warmer and more rarified air, must give rise to gyrations around the center from right to left in the northern hemisphere, with gyrations the contrary way in the exterior part, and these gyrations in contrary directions must give rise to gradients of pressure increasing in the central part from the center outward, but in the external part to a gradient of pressure increasing from the outward limit of the gyrations toward the center, so that there must be a belt of high pressure with its maximum where the interior gyrations in proceeding from the center, vanish and change signs. These exterior gyrations and the gradients arising from them are generally small in comparison with those of the interior, and they are generally so interfered with by numerous irregularities, that they are not readily shown by observation, but to deny that they exist, would be to deny the truth of a fundamental and well established principle in mechanics.

The increased pressure under the belt of high barometer surrounding the central part of the cyclone causes a modification of the flow of air toward the center very near the surface, for the air is forced out from beneath in both directions, the flow toward the outward border very near the surface counter-

acts and reverses the flow toward the center arising from the primary and initial cause of disturbance, while the part pressed out on the interior side toward the center, combines with this flow toward the center and increases it. For the same reason in the general motions of the atmosphere the flow of air below from the polar to the equatorial regions is reversed very near the surface, and the gentle southwest winds of the middle latitudes are produced.

The preceding condition, found in the unequal distribution of temperature, must be regarded simply as a primary cause of disturbance, giving rise merely to the initial cyclonic disturbances; for without other conditions, depending upon the hygrometric state of the atmosphere, and upon the rate of decrease of temperature with increase of altitude in the atmosphere generally in which the cyclone exists, we could have no cyclone of long continuance or of much violence. With a dry atmosphere the air in the ascending current of the interior would cool about one degree centigrade for each 100 meters of ascent, so that the air at a very moderate elevation would become colder and more dense than that of the strata of the surrounding atmosphere at the same altitude. The pressure then of the air at the surface in the interior would become equal to or greater than that of the air generally, unless the rate of decrease of temperature with increase of altitude in the latter were greater than 1° C. for 100 meters, which it never is except in some rare cases and very near the earth's surface only. When this would take place the initial cyclonic disturbances arising from this primary cause of disturbance would cease.

If the air is nearly saturated with aqueous vapor, after ascending to only a moderate elevation its tension and temperature are so much diminished that the vapor is condensed into cloud and rain and the heat given out in the condensation of the vapor as the air ascends prevents the rapid cooling which takes place in dry air and the rate of cooling with increase of altitude is reduced, in ordinary temperatures and elevations, to less than half of what it is in dry air. If in this case the rate of decrease of temperature with increase of altitude in the surrounding atmosphere generally is less than that in an ascending current of saturated air, then the temperature of the air in the ascending current, at all altitudes, must be less than that of the air generally, and hence the column of ascending air is lighter than the surrounding air, and the ascending current is kept up as long as it is supplied with air nearly saturated. If, however, after a time, this current comes to be supplied with dryer air, then it has to ascend to a much greater elevation before condensation of the vapor takes place, and as

it cools at the rate of 1° C. for each 100 meters before it reaches that elevation, it may be cooled down lower than the surrounding air before reaching the elevation where condensation commences, so that if, in this case, we should have the conditions of a continuing cyclone at all, the power of the cyclone would at least be very weak.

Where the state of the atmosphere is such, whether dry or saturated with moisture, that the rate of decrease of temperature with increase of altitude is greater than in an ascending current, it is said to be in a state of unstable equilibrium, since if from any slight predisposing cause such ascending current is once set in motion it must continue until this state is changed, either by the action of what we have called the primary causes of disturbance of temperature or from the inverting action of the currents set in motion. But an atmosphere in this state over a large area would not furnish the conditions for a large cyclone, but there would be simply a bursting up of the lower strata through the upper ones at various places, giving rise to numerous local showers, and often to tornadoes and hailstorms. In order to have the complete conditions of a large cyclone it would be necessary to have a central region of warmer and more rarefied air to set in motion ascending currents over a considerable area, and with this there might be considerable cyclonic disturbance if the atmosphere were not quite in the state of unstable equilibrium, but without this latter condition also we could not have a long continued cyclone. It is seen then that the moisture of the air is a very important element, since without this we cannot have the state of unstable equilibrium unless the rate of decrease of temperature with increase of elevation in the atmosphere generally is greater than 1° C. for each 100 meters, but where the air is saturated this condition takes place with a rate of decrease less than half as great, a rate of decrease which is often found in the atmosphere. The more nearly the air is saturated with vapor, and the greater the decrease of temperature of the air generally with the increase of elevation, the greater is the power of the cyclone. But without these there may be considerable cyclonic disturbance kept up for some time, arising from the primary causes of disturbance, even where the air is so dry that there is very little condensation of vapor into cloud and rain. Professor Loomis has shown that there is sometimes a considerable barometric depression for several days with little or no rain, but in such cases there are only small gradients with no violent winds, and the depression only becomes considerable from the gradients extending over a large area. At the equator where there is no gyration of the area of rarefaction around its center in virtue of the earth's rotation

around its axis there cannot be any gyratory motion, but the interchanging motion between the central and external part is entirely radial. Cyclones are therefore never observed on or very near the equator.

If there were no friction between the air and the earth's surface, all the conditions of a cyclone could be satisfied by circular gyrations without any radial motions, except in the initial state before the radial motions are brought to rest by means of the friction between the different strata. In this case the linear velocity of the gyrations would be very great near the center. The greater the amount of friction between the air and the earth's surface the less is the velocity of these gyrations, and the greater the inclination of the direction of motion at the earth's surface from the direction of the tangent toward the center. This is shown by the mathematical expression of this inclination deduced from the solution of the equations expressing the conditions of a cyclone, and this same expression shows that near the center of a cyclone the gyrations at the surface are more nearly circular than at greater distances from it, and that, all other circumstances remaining the same, the nearer the equator the greater the inclination, so that at the equator it becomes 90°, and the motion, as already stated, is radial. In the exterior, or anticyclonal part, where the gyrations are reversed, this inclination at the earth's surface is outward from the tangent. At all altitudes some distance above the earth's surface the friction is small and the gyrations are more nearly circular, but a little inclined toward the center in the lower part where the interchanging motion is toward the center, but outward from the center above, where this motion is from the center.

If any central area for some reason could be kept colder than the surrounding parts, with a gradient of temperature increasing somewhat regularly from the center outward, we should have the condition of a cyclone with a cold center. This condition is furnished in some measure by an island in a northern sea in winter, on which the temperature is less than on the surrounding ocean. In such a case the interchanging motions below and above would be reversed, but the gyrations would be in the same direction around the center in the interior part as in the case of an ordinary cyclone, and the contrary in the exterior part. The general motions of the atmosphere on each hemisphere of the globe, with the cold poles as their centers, are simply two examples of cyclones of this sort. The gyrations here, in the northern hemisphere, are around the pole from right to left, as in an ordinary cyclone, and the contrary in the southern hemisphere, while at a certain distance from the center, or pole, these gyrations

vanish and change signs, then giving rise to the anticyclonal part of the system, as in an ordinary cyclonic system.

A local cyclone of this sort, with much violence or long continuance, cannot take place. For if there was a central colder area which would give rise to the initial motions of such a cyclone, the air in its descent in the interior would become 1° C. warmer for each one hundred meters of descent, and hence the colder initial temperature of the central part would soon be so increased as to equal that of the atmosphere generally surrounding, when the condition giving rise to initial motion would be destroyed and all motion cease. In such a case there would be no advantage in a moist atmosphere, since if it were even saturated as soon as descent in the interior would commence, it would become unsaturated. Hence we never have any violent cyclones of this sort, and nothing more than initial disturbances which continue generally only a short time.

Fixed Cyclones.—Where the primary cause of temperature disturbance is fixed to one spot on the earth and kept up continuously, it gives rise to a fixed cyclone. Such an example is furnished by a warm island surrounded by a colder sea. This, unless it were very near the equator, would give rise to considerable cyclonic disturbance, and, if the island were of considerable extent, to an observable barometric depression. A very remarkable example of such a cyclone exists in the northern part of the Atlantic ocean. Here, on account of the Gulf Stream and the general interchange of waters between the equatorial and polar regions, which tend to equalize the temperatures, there is a considerable area of warmer temperature, especially in the winter season, than that of the sorrounding parts, with its center near Iceland. This gives rise to a fixed cyclone with its interior gyrations around this center and fixed area of low barometer extending over the greater part of the northern part of the Atlantic ocean. These gyrations on the southern side of this cyclone, combining with those of the general motions of the atmosphere, cause the strong west winds and steep gradients in the middle latitudes of this ocean in the winter. The belt of high pressure of this cyclone is thrown somewhat, on the south side, upon that due to the general motions of the atmosphere at the parallel of about 30° or 35°, and causes the area of high pressure in this ocean at these latitudes.

In the summer season the temperature gradients nearly disappear, and there is very little cyclonic disturbance over this region or barometric depression in the vicinity of Iceland. Very similar conditions exist in the northern part of the Pacific ocean, but the cyclonic disturbances and the decrease of barometric pressure are not so great.

Progressive motions of Cyclones.—Ordinary cyclones, at least soon after their first formation, become independent of local circumstances connected with the earth's surface. The primary temperature disturbance is not sufficiently great and permanent enough to hold the cyclone to the spot where it originates, and it is carried forward by the prevailing general movements of the atmosphere, and the central area of warmer air is maintained by the heat arising from the condensation of the vapor in the interior ascending currents supplied with moist air from the earth's surface by means of the horizontal currents flowing in from all sides toward the center. The direction of progressive motion, therefore, is somewhat in the direction of the general motions of the atmosphere in all parts of the earth. Hence cyclones originating near the equator, where there is a westward component of motion, are carried westward, but those originating in the middle latitudes, where the general motion of the atmosphere is eastward, are carried toward the east. There is also a tendency of cyclones to move toward the poles where there are no general currents to carry them forward. Cyclones, therefore, which originate in the Atlantic near the equator are first carried westward and northward toward the West India islands, and Florida, until they arrive at the parallel of about 30°, where there is no east or west component of motion, and where, consequently, they move in the direction of the meridian until they arrive at the middle and higher latitudes, where the general eastward current carries them in that direction, with an inclination still toward the pole. This seems to be the general tendency of cyclones originating everywhere near the equator, but they seem to make their way through toward the pole with greatest facility on the west sides of the Atlantic and Pacific oceans, because there the general motions of the air are deflected around somewhat toward the pole, and aid the cyclones in their progress and carry along a supply of moist air from the equatorial regions for their support. As the power of the cyclone is mostly in the upper cloud region of the atmosphere where the vapor is condensed mostly, the progressive motions of the cyclones depend rather upon the general motions of the atmosphere at considerable altitudes than upon those near the earth's surface. Hence within the tropics, where the westward motion is small above, the progressive velocity of the cyclone is small, and it is so at the vertex of the parabolic path where the motion is toward the pole, but after arriving at the higher latitudes where the upper general motion of the atmosphere has considerable velocity, the progressive motion of the cyclone is much accelerated, especially its eastward component.

It must not be supposed, however, that the progressive motion of cyclones depends entirely upon that of the air in which

the cyclone exists. It depends also very much upon the direction in which the greatest humidity of the air lies. The progressive motion of the cyclone is generally greater than that of the air, even in the upper regions, and consists rather in the continual formation of new cyclones a little in advance of the old ones, the latter gradually subsiding, and this new formation is mostly likely to occur in the direction of greatest moisture.

Areas of High Barometer.—These arise from the intersecting and overlapping of the circular belts of high barometer of different cyclones both fixed and progressive. In consequence of the gradients arising from the general motions of the atmosphere combined with those of the fixed cyclones and all the other irregularities, the gradients and isobars become very irregular. When to these are added the irregularities of progressive cyclones following and impinging upon one another, this irregularity becomes still much greater, so that it must frequently happen that there are areas in which the barometer stands higher than at any of the surrounding places, just as on a rough sea where numerous broad waves interfere and cross one another, the surface of the sea has elevations and depressions, not in the form of waves and troughs, but rather of elevated and depressed areas approximating more nearly to a circular form. The isobars of these areas are generally somewhat irregular, but still as they enclose an area, and the winds, according to a well-established law, must blow with a certain not very great inclination to these isobars, the motion of the air is somewhat around these areas in a direction contrary to that of the interior part of an ordinary cyclone. These areas, however, do not form systems of winds complete in themselves, but simply arise from the interference of cyclones, and are therefore not properly called anti-cyclones.

Tornadoes.—These are simply very small cyclones, extending over so small an area that the effect of the earth's rotation has no sensible influence, and the gyrations arise, not from the gyration of this small area around its center in consequence of the earth's rotation, but from a disturbed state of the atmosphere in which the tornado occurs which renders it impossible for the air to flow from all sides toward a center without running into gyrations around that center. This may be illustrated by means of a basin of water with a hole through the bottom in the center through which the water is allowed to run out. If the water is entirely at rest when the flow commences, there will be only a radial and very gentle motion of the water from all sides toward the center, without any gyratory motion, but if it has the least gyratory motion in its initial state, even entirely imperceptible, it will run into very rapid gyrations before reaching the center.

The effect of friction in tornadoes is much less than in cyclones. A cyclone of considerable extent may be regarded as a disk, with a diameter many times greater than its depth or thickness, and hence the gyrations are very much retarded by friction on the earth's surface; but a tornado is rather a pillar of gyrating air with a very small base in comparison with its altitude, and hence the retardation of the gyrations by friction on the earth's surface in this case is comparatively very small. The gyration of the air, therefore, except near the earth's surface, is very nearly in accordance with the principle of the preservation of areas, and hence the lineal gyratory velocity is very nearly inversely as the distance from the center, and consequently must become very great near the center.

In cyclones the barometric gradient and depression of the barometer in the central part are due both to the deflecting force arising from the earth's rotation and the centrifugal force of the gyrations, to the former mostly at a considerable distance from the center, but to the latter mostly near the center. In a tornado the diminution of pressure and tension in the center arises almost entirely from the centrifugal force, that depending upon the earth's rotation being nearly insensible. On account of the rapidity of the gyrations near the center this diminution of pressure may be very great there, while at a very short distance from the center it is imperceptible.

Tornadoes occur when, from any cause, the air is in the state of unstable equilibrium already referred to. This may be near the earth's surface, but is most usually up in the region of the clouds, where the air is saturated with moisture, and where consequently this state occurs most frequently, since it then requires a rate of diminution of temperature with increase of altitude usually less than half as great as in the case of dry air. When the atmosphere is in this state the air of the lower strata, from any slight disturbance, bursts up through the upper strata at some point, and the higher it ascends the greater is the difference between its temperature and density and those of the surrounding strata at the same elevation, and hence the greater the tendency to rush up at that point. But, as in the case of the basin of water, if the initial state of the air were that of quiescence, there would be only a radial flow of air from all sides toward that point without any gyratory motion or diminution of tension at the center, and with very little violence of motion. The velocity of the ascending current in this case would not be very great since the column of ascending air would soon spread out laterally, and become too great. In order to have, therefore, all the conditions of a tornado, it is necessary to have, besides the state of unstable equilibrium, the other conditions which, as in the case of the water in the

basin, give rise to gyrations around the central point toward which the air from all sides flows. When these gyrations commence above, as they usually do, since the air there is most frequently in the state of unstable equilibrium, they gradually extend downward for the gyrations cause a great diminution of tension and of density, and the air consequently in the center rushes up with great velocity and that below of the still unagitated strata is drawn in to supply its place, which likewise runs into gyrations around the center, so that the gyrations in a very short time extend down to the earth's surface. The whole column of gyrating air is like a tall flue containing very rarefied air, the centrifugal force of the gyrations acting as a barrier to prevent the inflow of air from all sides into the interior, and if the gyrations at the earth's surface were as rapid as those above, it would be similar to such a flue with all the draught cut off. But very near the earth's surface these gyrations, and consequently the centrifugal force, are very much diminished on account of the friction at the surface, and this allows the air to rush in quite near the surface to supply the draught of the interior ascending current. While, therefore, the gyrations above, on account of the little friction are almost exactly circular, allowing little air to reach the central part, the motion of the air, near the surface, is more nearly radial, or at least very much inclined inward from the direction of the tangent. It is the same somewhat in the case of large cyclones. Very near the earth's surface the radial component of motion is much greater than it is at a moderate elevation above, and the inclination from the tangent toward the center may be very great, while a little above the surface the gyrations are nearly circular. It is readily seen that this must be the case since the force which overcomes the friction of the gyratory motion depends, in both cyclones and tornadoes, upon the radial component of motion, and hence the greater the friction to be overcome the greater must be this radial component, and where there is little friction this radial component is very small and the gyrations nearly circular.

Where the air near the earth's surface is nearly saturated with moisture it has to ascend to only a very moderate altitude, at the outer border of the tornado, to have its tension and temperature so reduced that the vapor is condensed into cloud, and nearer the center, where the tension is diminished by the centrifugal force of the gyrations, the stratum in which condensation and cloud-formation commences is brought down to the earth at a considerable distance from the center. In such a case a considerable area of the earth's surface in the central part of the tornado is covered with dense cloud and enveloped in darkness. The indrawing, gyratory and ascensional currents

are so strong as to draw in and carry up very heavy bodies and throw them out above to a great distance. Sometimes the ascending current is so strong as to keep a heavy body suspended in the air for a long time until the tornado has progressed many miles, when, after the violence of the tornado begins to abate, the body falls to the earth. Unless the strength of the ascending current is sufficient to carry the body up to an altitude where the air tends outward from the center, the gradually indrawing currents below that altitude keep the body near the center and it cannot fall to the earth until the ascending velocity of the current which has carried it up, is diminished.

Waterspouts.—These are simply special cases of tornadoes, as tornadoes are of cyclones. Where the air at the earth's surface in a tornado is not nearly saturated with moisture, it has to ascend to a much greater elevation on the outward border of the tornado before cloud formation takes place, and also the nearly horizontal inflowing and gyratory currents below have to approach very near the center before cloud is formed, and the nearer the earth's surface, the nearer this approach must be. Hence, the base of the cloud assumes a funnel-shape above, with a long tapering stem reaching down to the earth or sea. A waterspout, therefore, is simply *the cloud brought down to the earth's surface by the rapid gyratory motions near the center of a tornado.* This may be explained by means of a deep vessel, instead of a shallow basin, of water with a hole in the center of the bottom. If the water is allowed to run out, and it has only an almost perceptible initial gyratory motion, it finally runs into very rapid gyrations around the center, and the surface of the water and each of the strata of equal pressure under the surface, assume a funnel shape at the top and extend down to the bottom, even within the hole, in the form of a long, tapering tube. It is the same in the case of the air in a tornado. The fact that the air of the lower strata runs upward through the upper strata, instead of downward through the bottom, does not alter the case, for the gyrations, upon which the lowering of the strata of equal tension and temperature depend, are produced just the same in both cases. The stratum of the air, then, of which the tension and temperature are such as to condense the moisture of the air, assuming this shape, of course the base of the cloud assumes the same. If the dew-point of the air at the earth's surface is 10° C. below the temperature of the air, then air at the outer limit has to ascend about 1,000 meters before cloud-formation takes place, and this determines the height of the spout. The distance from the center at the base, at which condensation and cloud-formation takes place, depends upon the rapidity of the gyrations, and this upon the amount of

initial gyration and of friction. In a tall, slender column of gyrating air the friction is small, and the gyratory velocity may be assumed to be very nearly inversely as the distance from the center, except very near the center, where the gyratory velocity becomes almost infinitely great. Without any friction the waterspout would always be brought down to the earth, it might be in the form of a mere thread, however small the initial gyrations, but in nature, where friction, at least near the center, must diminish considerably the velocity of the gyrations, this is not the case. The diameter of the base of the waterspout depends upon the gyratory velocity, and where this on account of friction near the center, is not sufficient to bring the spout down to the surface of the earth, it is seen merely as a funnel-shaped cloud.

Small waterspouts which are seen upon the sea or small lakes in perfectly clear and calm weather, arise from a state of unstable equilibrium of the clear but nearly saturated air near the surface of the water. The principle of their formation is the same, but a greater rate of decrease of temperature with increase of altitude is required, than when their first formation commences up in the region of the clouds.

Cloud-bursts.—We have seen how a heavy body may be sustained and kept up in the air near the center of a tornado for a long time. In the same manner a large accumulation of rain is sustained, and prevented from being dispersed by the inflowing currents so long as the rain is not carried up where the air flows out from the center. Calculation shows that the amount of rain condensed from nearly saturated currents of air with such velocities as must exist in the central parts of tornadoes is enormous. The water cannot fall in drops on account of the strength of the current. It therefore accumulates in the body of the cloud, and especially at points where the ascending current is least, until the weight of water becomes so great that it is poured down through the air in streams. Where these streams strike the earth's surface they excavate great holes in the earth, often several yards deep, and if this occurs on a mountain side, great ravines may be produced. That these holes in the earth and ravines are caused by a stream of water, and not by a very heavy rain, is evident from the fact that the sides of these holes are often cut down almost perpendicularly, while leaves and other light substances, where these holes occur on mountain sides, remain undisturbed near the border on the upper side. The ascending current keeps rain-drops from falling, so that no water falls except in the down-pouring streams.

Cloud-bursts are most apt to occur on mountain sides. The tornado, heavily loaded with accumulated rain-water, on approaching a mountain side is very much interfered with by it.

The draught of the ascending current, as we have seen, is mostly near the earth's surface. When the base of the gyrating column of air strikes the mountain side, this draught is somewhat cut off, and the whole system somewhat broken up, and the power of the tornado destroyed. Hence the whole accumulation of water is sometimes poured down, almost at once, on the side of the mountain, tearing up rocks and trees, and causing a great ravine.

Hail-storms.—As in tornadoes, there is a stratum of air brought down to the earth by the centrifugal force of the gyrations, where the condensation of vapor into cloud and rain first takes place, and which assumes the figure of the water-spout, so very much higher up there is one brought down, it may be entirely to the earth, where the tension is so small and the temperature so low as to freeze the vapor into snow and the rain-drops into hail, even in the summer season. The altitude of this stratum, where it is not brought down to a lower level by the gyrations, depends upon the excess of the temperature of the air at the earth's surface above the freezing point. Drops of rain carried by the ascending current above this stratum, or where it is brought down to or near the earth, within it, are frozen into hail. These may be carried outward above where the ascending currents are so weak that they can fall to the earth, and as they may fall very slowly and may have been cooled down considerably below the freezing point, they may continue to increase in size all the way down by freezing the water which adheres to their sides in falling, for the ascending current would bring a great deal of rain in small drops and mist in contact with them.

Sometimes much of the hail in thus falling is drawn in toward the center by the inflowing currents from all sides below, until there is a great accumulation of hail in the center of the tornado, just as of rain in the case of a cloud-burst. If from any cause, then, the strength of these currents should become suddenly weakened, or the whole system broken up, all this hail would fall rapidly to the earth, and hence the almost incredible amounts of hail which are said to fall sometimes in a very short space of time.

A considerable amount of rain may be carried some distance up into the snow region before it has time to freeze. By the mixture of rain and snow, small balls of very moist snow are formed, which, being carried out where the strength of the ascending current permits them to fall slowly, they continue to grow until they become heavily coated with solid ice, and finally reach the earth. It is in this way that the large hail-stones with a snowy kernel within are formed. But these in falling are sometimes carried by the indrawing current below

into the central part of the tornado, where the ascending currents are strong enough to carry them up again into the region of soft snow mixed with rain, where they receive another coat of soft snow, less compact than the coat of ice, after which they are thrown out again above where they fall gently down and receive another coat of solid ice. This may be repeated a number of times, the hail-stone moving in a sort of oval orbit, upward in the central part, outward above, and down at a distance from the center where the strength of the ascending current is such as to allow it to fall, and then toward the center again, to commence another similar revolution. While in the upper snow region it receives a coat of snow, and while in the region of cloud and rain, a coat of solid ice. Hence it is no unusual thing to find large hail-stones composed of a number of coatings like an onion, these coatings consisting of alternate layers of frozen soft snow and solid ice.*

Sand-spouts.—These occur mostly on dry, sandy deserts, where the surface becomes very much heated, and the rate of decrease of temperature with increase of altitude is such that the unsaturated and almost entirely dry air is in the state of unstable equilibrium. The sand-spout originates just as any small tornado, or as small waterspouts upon lakes in fair weather, but the air is so dry that there is no condensation of vapor, unless it is at a very great altitude, but the indrawing and ascending currents carry with them a great quantity of dust and other light substances, which assume the form of a pillar extending high up into the air. As occurs in all tornadoes and waterspouts, the air flows in from all sides below to supply the draught of the ascending current, mostly near the earth's surface, but also in some degree up to a considerable altitude, and these inflowing currents drive the dust which is raised on all sides, in toward the central part, and thus the dusty part of the air assumes the figure of a column.

As the particles of sand gyrate rapidly with the air, the centrifugal force of the gyrations tends to drive the particles from the center, but this is counteracted by the resistance of the indrawing currents, which is a function of the size of the particle and the strength of their currents, since it is nearly as the square of the product of the velocity of the current into the diameter of the particle. Hence, particles of sand of different sizes arrange themselves at different distances from the center, the smaller particles penetrating nearer the center, since the centrifugal force is as the cube of the diameter, while the resistence of the inflowing current is nearly as the square of the diameter. If, however, the particle were very large, it might

* See American Journal of Science, II, vol. l, p. 403.

be kept at so great a distance from the center, that the ascending current there would not be able to keep it up, so that if there were no limit to the sizes of the particles, yet there would still be a limit to the dimensions of the pillar of sand, which would be determined by the ascending velocity of the air at different distances from the center.

Water-spouts and Sand-spouts are hollow.—Near the center of the gyrations the centrifugal force is so great that the small particles of condensed vapor in waterspouts, and of fine sand particles in sand-spouts, cannot exist there, or at least they are comparatively rare, so that these spouts have the appearance of being hollow. M. Boué, in the year 1850, observed three water-spouts at the same time on Lake Janina, from the top of a high mountain. The weather was entirely clear, without clouds or wind, but very oppressive and hot. The spouts seemed to rise up from the lake, and he could look down into the top of them and see that they were hollow in the middle. (Bulletin Soc. Geologique de France, v. viii, p. 274.)

Of a whirlwind observed at Schell City, Mo., in the summer of 1879, Professor Nipher says: "There were no surface winds strong enough to bear dust along the surface of the ground, but the dust carried up in the vortex was collected only at the vortex of the whirl. The dust column was about two hundred feet high and perhaps about thirty or forty feet in diameter at the top. The direction of rotation was the same as of storms of the northern hemisphere. Leaving the road the whirl passed out on the prairie, immediately filling the air with hay, which was carried up in somewhat wider spirals, the diameter of the cone thus filled with hay being about one hundred and fifty feet at top. It was then observed also that the dust column was *hollow*. Standing nearly under it, the bottom of the dust column appeared like an annulus of dust surrounding a circular area of perfectly clear air. The area grew larger as the dust was raised higher, being about fifteen or twenty feet wide when it was last observed." (Nature, Sept. 11th, 1879.)

ART. VIII. — *Magnetic Observations made in Davis Strait, in August and September*, 1880, *on board the Steamship Gulnare;* by O. T. SHERMAN.

THE Steamship Gulnare was provided with a Lamont magnetometer, made by Fauth & Co., and a Kew dipping needle, made by Cassella. Before the starting of the expedition, both instruments were set up in the private observatory of Mr. C. A. Schott, in Washington, and the observers had the great benefit of his advice. The methods of observation, the forms of record and reduction are recorded, in part, in Appendix No. 16, Coast Survey Report, 1875, in part in the "Admiralty Manual of Scientific Inquiry." Frequently, however, it was found desirable to have recourse to the sextant to obtain the azimuth.

The first observations we record were taken at St. John, N. F., part at the private observatory of Mr. John Delaney, part on the hill forming the harbor. A local publication containing information "derived from the most authentic sources," gives the variation for 1880, as 32° 30′ West. The authority is not known. Commander Robinson, R. N., observed in 1878 a value 31° 30′. The variation chart, for 1880, published by the British Admiralty, shows the line of 31° running through the harbor. Our own value is 30° 40′. It is derived from five observations, four of which are absolutely independent. The extreme values differ among themselves by 6′·1 when reduced to the mean of 24 hours. This discrepancy I am at a loss to explain. No data are known which would refer it to local attraction. The horizontal force observed was 3·3373, the dip 74° 45′·4.

Lively, Disco Island, Greenland, formed our second station. This place had formerly been visited by Sontag in Sept., 1861, who found the dip 81° 51′ and the horizontal force 1·762, but who records no declination. It was again visited by the Alert and Discovery in 1875; the record then made the declination 67° 12′·8–68° 45′, dip 81° 56′–81° 43′·7 and horizontal force 1·770–1·805. Total force, 12·514–12·578. The remark is added that the observations showed evidence of considerable local attraction. Our record is one of disturbance only. On August 11th, the declination observed by the magnetometer varied from N. 46° 9′·7 W., at $11^h\ 13^m$ A. M., to N. 49° 15′·3 W., at $4^h\ 32^m$ P. M. On August 18th, at the same spot, but with an azimuth compass, the declination varied from N. 67° 54′·1 W., at 7 A. M., to N. 68° 52′·4 W. at 3 P. M. Our needle was consequently deflected over twenty degrees by the magnetic storm of August 11th. On several successive days also, it was

our custom, as the ship swung with the tide, to observe the errors of the ship's compass by reference to a fixed and distant mark. As yet, however, we have been unable to derive from them a series of values, which makes the ship's constants at all comparable with the same values derived elsewhere; whether from local attraction or magnetic storm, those who can refer to continued observation must determine. On August 12th, the magnetometer gave a horizontal force of 1·9042. On August 14th, in the same position as the declination of the 11th and 18th, 1·7559. On September 1st, at a station almost midway, 1·8842. These values correspond in magnitude to the distances from one of the many gneiss knobs. Feeling uncertain, therefore, as to the extent to which the observations might be affected by local attraction, more especially as observations from stations in the Waigat corresponded but poorly with those at Disco, we determined, on our return, to endeavor to discover some place which might be free from local influence. Taking the dipping needle, we made observations from the top of the hills to the sea coast. Placing these on the chart they are found to increase in value on either side of a knoll of trap rich in magnetite, on which the dip was 80° 48′. Half way up the hill it became 81° 6′, on the top of the hill, 81° 23′. Speaking generally, the line 81° 50′ runs from a point half way between Wildfire and Englishman's Bays, along the inner shore of the island forming the harbor. The line of 82° runs through the middle of the western part of the island and on the sea shore on the eastern. The line of 82° 6′ on the western sea shore. All lines form a loop in the direction of Crown Prince islands. We found no spot free from local influence. A stone was brought to me while here, which both Prof. Steenstrup and myself recognized at once as "Ovifak meteoric iron." It was said to have been found in Wildfire bay. From what we now know, however, it seems more likely to have been brought by the natives from Ovifak. They keep a number of these stones on hand for purposes of trade.

At Rittenbenk, lat. 69° 44′, long. 51° 2′ W., we found on August 23d, 1880, the dip to be 81° 53′·9, the total force 12 6213, and the variation N. 70° 2′·9 W., at $11^h\ 30^m$ local time. The Alert gives for this station a declination of 69° 8′·5 at 6·40 P. M. The station is granitic and there may be local attraction.

At Sakkak, lat. 70° 1′ N., long. 51° 55′ W., we found on August 24th, the dip to be 81° 59′·6, variation N. 70° 47′·3, at $12^h\ 15^m$ local time; and on August 31st, the horizontal force 1·7904. This station is also probably affected by local attraction.

At Kidluset, lat. 70° 10′, long. 53° 0′, August 25th, 1880, we observed a dip 82° 11′·8, and total force 12·5435. These are probably not affected by local influence.

The Gulnare was a wooden ship with iron frame. She had seen many years' service in the waters of New Foundland, but during the winter before the expedition sailed, had been almost entirely rebuilt. She was swung at Hampton Roads, on June 23d, 1880. The observations discussed by the method of least squares give the value of the ship's force to head, −1·8403, to starboard, −0·7845. Three days after, the salt which the engineer had allowed to collect in the boiler reached a thickness of several inches and the fire boxes collapsed. These were replaced at St. Johns and for ten days and nights the iron in that part of the ship was again subjected to hammering. The ship was again swung at St. Johns. The value of the ship's force reduced, after Evans, by the least squares are force to head, −1·916, to starboard, −0·2599, to nadir, −0·4081. On August 30th, the values were, force to head, −1·46299, to starboard, −0·83918. On October 5th, the values became to head, −0·9971, to starboard, −1·4525, to nadir, −0·3907. A change I should be loath to accept were it not thrust upon me by the facts of navigation. The swing of October 5th was necessitated by the discrepancy between the observed and calculated courses. It was our custom at sunrise or sunset to observe the angle between the sun's limb and the line of the ship's keel, noting at the same time the ship's heel and course by the disturbed compass. These observations served at the time to correct our course. Several of these have been again employed to give us the declinations at the place of observation. The ship's forces for the date were obtained by simple interpolation from the values above given. These connected with the soft iron coefficients give us readily the values of the semi-circular variation. These, finally, we have placed in the exact expression

$$\sin\ \delta = \frac{AC \pm B\sqrt{-C^2+A^2+B^2}}{A^2+B^2}$$

which is readily deduced from Evans' well known formula. A, B and C are here easily calculated functions of the semi-circular and quadrantal coefficients, and the ship's apparent azimuth. The sign + being taken, when the compass reading is from N. 0° E., to N. 180° E., the sign − for the remaining readings. The values obtained in this way are as follows:

Date.	Lat. N.	Long. W.	Hour, P. M.	Declination.
August 5, 1880,	62° 30′	51° 45′	8 23	N. 57° 42′ W.
September 10,	67° 6′	58° 30′	6 43	N. 70° 59′ W.
September 14,	59° 30′	56° 26′	6 27	N. 57° 29′ W.

Art. IX.—*On the Crystalline form of Sipylite;* by J. W. Mallet.

In the original description* of the mineral in question from the allanite locality in Amherst Co., Va., very little could be said about the crystalline form, as but a few imperfect faces had been met with. I have recently obtained some additional specimens, most of them irregularly shaped nodules imbedded in allanite, but fortunately among them one nearly complete detached crystal, broken into two parts indeed, but these fitting accurately together, so that the form can be easily made out.

This little specimen is a tetragonal octahedron, 1·5 centimeter long, weighing 1·627 grm. No faces are visible save those of the octahedron (1) and faint indications at one or two places of an extemely narrow plane replacing its terminal edges. The surfaces are too dull to allow a reflecting goniometer to be used, but an application goniometer gives the angles

$1 \wedge 1$ (over summit)$=53° 0'$
(Hence $O \wedge 1 = 116° 30'$)
$1 \wedge 1$ (adjacent pyramidal)$=100° 45'$
$1 \wedge 1$ (basal)$=127° 0'$

These measurements show a close relation to fergusonite, for which

$O \wedge 1 = 115° 46'$
$1 \wedge 1$ (pyramidal)$=100° 54'$
$1 \wedge 1$ (basal)$=128° 28'$

The relation in form between fergusonite and tapiolite and xenotime on the one hand, and scheelite, stolzite and wulfenite on the other has been pointed out by Rammelsberg.† The angles for sipylite and for fergusonite are connected with those of xenotime if a of the two former be taken $=2a$ of the latter, and this,‡ as well as Rammelsberg's analysis of fergusonite, supports the view expressed in my former paper that sipylite is an ortho-niobate—$R''_3 M^v_2 O_8$—containing basic hydrogen.

The sipylite crystal shows distinct cleavage parallel to 1. It is fully identified with the mineral originally examined by its general physical characters. The sp. gr. $=4·883$ at 16° C.; formerly found, 4·887 at 12°·5, and 4·892 at 17°·5.

Univ. of Virginia, May 21, 1881.

*This Journal, 397, Nov., 1877. †Jour. Chem. Soc., 189, March, 1872.

‡Taking the usual, and probably correct, view of xenotime, that it is an ortho-phosphate. But no great weight can be attached to any opinion as to yttrium compounds until the confusion at present existing in relation to the metals which have together passed under this name has been cleared up.

ART. X.—*Observations on the Structure of Dictyophyton and its affinities with certain Sponges;* by R. P. WHITFIELD.

IN the Chemung group of New York, and in the Waverly beds of Ohio and elsewhere, there occurs a group of fossil bodies which have been described under the name *Dictyophyton*, but the nature of which I think has not been properly understood. In the 16th Report on the State Cabinet of Natural History of New York, page 84, in the remarks preceding the generic description, they are referred to the vegetable kingdom with the opinion expressed, "that they are Algæ of a peculiar form and mode of growth." A reference which I think their nature does not warrant.

If one examine the figures of the various species described, given on Plates 3 to 5A of the above cited work, it will be seen that these bodies are more or less elongated tubes, straight or curved, cylindrical or angular, nodose or annulated; and that they have been composed of a thin film or pellicle of net-work, made up of longitudinal and horizontal threads which cross each other at right angles, thereby cutting the surface of the fossil into rectangular spaces; often with finer threads between the coarser ones. When the specimens, which are casts or impressions in sandstone, are carefully examined, it is found that these threads are not interwoven with each other like basket work, or like the fibers of cloth, nor do they unite with each other as do vegetable substances; but one set appears to pass on the outside, and the other on the inside of the body. The threads composing the net-work vary in strength, and are in regular sets in both directions, while the entire thickness of the film or substance of the body has been very inconsiderable. In one species, the only one in which the substance filling the space between the cast and the matrix has been observed, it appears to be not more than a twentieth of an inch in thickness, and is ochreous in character. This peculiar net-like structure does not seem to be that of any known plant, nor does their nodose, annulated, cylindrical or often sharply longitudinally angular form, with nearly perfect corners, indicate a vegetable structure; moreover, it is not a feature likely to be retained in a soft, yielding vegetable body of such extreme delicacy and large size, while drifting about by the action of water, in becoming imbedded in the sand of a sea bottom, but would rather indicate a substance of considerable rigidity and firmness of texture.

In examining the structure of *Euplectella* it is found to be composed of longitudinal and horizontal bands similar to those above described, with the additional feature of sets of fibers

passing in each direction obliquely across or between the longitudinal and horizontal sets, but not interwoven with them; so that the longitudinal series forms external ribs extending the length of the sponge, and the horizontal series inside ribs or bands, and they appear as if cemented to each other at their crossings. The oblique threads, besides strengthening the structure, cut across the angles of the quadrangular meshes formed by the two principal sets of fibers, and give to them the appearance of circular openings, making the structure much more complicated than in *Dictyophyton*. The addition of oblique fibers in *Euplectella* is the most noticeable difference between the two forms; but if placed horizontally and longitudinally between the primary sets they would produce precisely the structure seen in *Dictyophyton*.

As yet we have no positive evidence of the nature of the substance which composed the fibers in *Dictyophyton*. The only cases known, so far as I am aware, of the preservation of the substance of the fossil is that mentioned above, where the space between the matrix and the cast is occupied by a ferruginous body, a material which so often replaces siliceous organisms in a fossil state, and specimens of *D. Newberryi* from Richfield, Ohio, on which there occur slight patches of a carbonaceous substance, but not sufficient to warrant the conclusion that it ever formed a part of the structure, even in the opinion of the author of the genus who supposed these organisms to have been of vegetable origin; especially as they are associated with numerous fragments of terrestrial plants. I am therefore led to the opinion, from their firmness of texture as evinced by the strong markings left in the rock, and the almost perfect retention of their original form, that they were of a siliceous nature. Still, in this opinion I may be mistaken, and it must be left for future discovery to determine; but that they were of the nature of sponges and not of plants I feel very confident.

The form given by Professor Vanuxem in the Geological Report of the Third District of the New York Survey, and also figured in the 16th Report above cited, I think would also better conform to this idea than to that of a vegetable origin, although its broad flattened bands may be something of an objection.

The name *Hydnoceras* was originally applied by T. A. Conrad to designate a species of this genus (Jour. Acad. Nat. Sci. Philad., vol. viii, 1st series, p. 267), but was discarded on account of its objectionable signification, though if the view here suggested prove correct the later appellation is almost as objectionable.

ART. XI.—*The Carboniferous Rocks of Southeast Kansas;* by G. C. BROADHEAD.

AT the eastern boundary of Miami County, Kansas, we find the high lands to vary from 950 to 1050 feet above the sea, the valleys being 875 to 910. In the Neosho Valley the elevation at Neosho Falls is about 1000 feet. Up to this place and a little farther we pass over a gently sloping country. It then rises more rapidly, being 1150 feet on higher land. West of the Verdigris the country rises more rapidly and is more rugged.

In Osage County coal is profitably mined, which, according to Prof. Mudge belongs to the Lower Coal-measures. The Lower Coal-measures pass southwardly along the Neosho Valley which seems to occupy a trough in these measures, but eastwardly, including Miami County, the northern half of Anderson and the county northwardly, only the upper series are exposed, connecting with similar measures in Missouri.

West of the Verdigris River the Upper Coal-measures also extend but soon disappear beneath the "Permian." The main productive Coal-measures of Southeast Kansas lie south of Miami County. Passing from Paola southwestwardly to Greenwood County, we find only a thin coal-seam occasionally mined but with no profitable result. Near the line of Greenwood and Woodson Counties a seam of less than a foot thickness is sometimes mined. This is the most western exposure of coal belonging to the Carboniferous formation. In the western part of Woodson and in Greenwood County the lowest exposed rock is 50 feet of coarse sandstone which I have referred to the Lower Coal-measures, but only a few fragmentary remains of plants were found in it. Above this are thin limestone beds full of *Fusulina cylindrica* and nearly 200 feet more of sandstone, with other limestone beds above, containing well known Carboniferous fossils, including *Fusulina cylindrica* and *Chætetes.* The step now is more rapid to the "Permian."

Entering the State near the line of Cowley and Chautauqua counties, we find ourselves upon a long dividing ridge extending and well defined for seventy miles northwardly.

This ridge is much higher than the country either east or west of it, and is known in southern Kansas as the "Flint Hills," on account of numerous fragments of flint lying strewn over the surface. It includes the Permian rocks of Kansas and might appropriately be termed the "Permian Mountains." Its elevation above the sea is 1560 feet near Greenfield, in northeast part of Cowley County 1600 feet; and the highest point near the corner of Greenwood, Elk and Butler about 1700 feet. This is the

highest ground east of Arkansas and Walnut Valley. On the west side of this ridge the descent is gentle and scarcely perceptible, being 390 feet in 25 miles to the Arkansas Valley. On the east the descent is more abrupt, the ridge presenting rugged walls of limestone separated by shaly slopes, and the hills descend 350 feet in four miles or 390 feet in six miles, and in some places the descent is still more abrupt. From the main ridge sharp spurs extend off from six to ten miles eastwardly. From the peculiar rough character of the eastern face of this ridge good wagon passes are often distant as much as ten miles.

The approaches to this ridge from Fall River Valley is by a succession of terraces or plateaus of upper Carboniferous rocks. At Twin Falls we are on a lower terrace elevated about 1000 feet above the sea. The second terrace is reached six miles southwestwardly at 1160 to 1180 feet. This terrace occupies a large area of the eastern part of Greenwood County with most of Elk. The elevation of the next terrace is about 1300 feet above the sea and it reaches to the foot hills of the Permian and the slopes above blend with the Permian. This will include altogether about 500 feet of Upper Coal-measure rocks in this part of Kansas which lie below the Permo-carboniferous. These beds are mainly shaly sandstones with occasional limestone beds, and as far as observed contain one coal bed of seven inches with two beds of bituminous shale, and one other coal seam of five inches thickness appears just beneath the Permian. The Permian or Permo-carboniferous of the "Flint Hills" include a total of about 500 feet thickness. The following section I have condensed from several taken within twenty miles.

1. Sixty-two feet including chert layers with thin beds of shaly drab-colored limestone; the highest rocks seen in "Flint ridges," observed *Bryozoa* with *Athyris subtilita*, *Productus costatus* and *Hemipronites crenistria*.

2. Ninety feet mostly thin limestone layers chiefly disintegrating on exposure.

3. Seven feet bed of porous chert resting on limestone. *Pinna peracuta* found everywhere. A *Phillipsia* was also obtained.

4. Eighty-five feet chiefly drab shales with some thin layers of limestone and red shale near lower part. Fossils are very abundant and can be picked up in a finely preserved state, and include *Fistulipora* (?), *Productus Nebrascensis*, *P. semireticulatus*, *Meekella striaticostata*, *Chonetes graculifera*, *Terebratula bovidens*, *Athyris subtilita*, *Yoldia subscitula*, *Schizodus Rossicus*, *Myalina perattenuata*, *Hemipronites crenistria*, *Aviculopima Americana*, and other known Upper Carboniferous fossils.

5. Five feet of bluish drab and sometimes buff limestone containing *Eumicrotis Hawni*, *Myalina perattenuata*, *Aviculopecten occidentalis*. [This bed is easily recognized wherever seen.]

6. Ten feet red and green shales.

7. Fifty-three feet beds shale, with some beds of limestone very good for building purposes.

8. Twenty-eight feet limestone abounding in *Fusulina cylindrica;* the middle layers contain blue chert full of *Fusulinæ* showing the structure very finely.

9. Twenty-eight feet of sandstone.

10. Four feet gray limestone containing *Productus semireticulatus*, *Allorisma granosa*, *A. subcuneata*, *Pinna peracuta*, *Nautilus capax*, etc.

The last bed I regard as the base of the Permian.

Other fossils obtained at the several localities include *Allorisma subelegans*, *A. Topekaensis*, *Macrodon* —, *Nautilus occidentalis*, *Murchisonia* —. Although these fossils seem at home in the *Permian*, I have obtained them also, with scarcely an exception, from known Upper Coal-measure rocks of Missouri; in fact most of them have been obtained from the rocks of Kansas City.

The limestones of the Permian have been extensively quarried in Kansas from the southern to the northern part of the State, and many tons sent off to the market. Some of the rock quarried is too soft for valuable structures, but many very excellent quarries have been opened.

From levels taken on corresponding beds wide apart, we find there is a regular dip westwardly of not less than 25 feet per mile. Assuming this to be correct we may be safe in saying that there are 1500 feet total thickness of Permian beds in southern Kansas. In the counties of Butler, Cowley, Elk and Greenwood, it is the *newest* rock below the *Quaternary*. No other rocks of later formation than the Permian are found here. The PERMIAN of Kansas rests *conformably* on the *Coal-measures* and there is no decided line of separation between the two. Certain strata can be grouped together as can certain other strata of other formations.

The only marked difference is this: Passing a certain horizon in the ascending series, we find the rocks to be all of a drab, buff or cream color and the limestones more impure and breaking with a rough fracture, and when vertically jointed the angle more nearly approaches a right angle, whereas the Coal-measure limestones are generally more acutely jointed and the blocks are regular rhomboids.

The group of the PERMIAN MOUNTAINS forms an interesting study; the strata are easily traced and the scenery afforded is very fine and views extensive.

The above is an abstract of a more detailed paper.

ART. XII.—*The Later Tertiary of the Gulf of Mexico;* by E. W. HILGARD, Berkeley, Cal. With a map (Plate III).

IN view of the late publication of the Coast Survey chart of soundings in the Gulf of Mexico, and of the observations of Dr. Eugene A. Smith on the Geological Formations of Florida (this Journal, April, 1881), I desire to summarize briefly the facts upon which my hypothesis of a temporary and partial isolation of the Gulf from the Atlantic Ocean during the later portion of the Tertiary period, is based. I shall add thereto some additional facts that have since been brought to my knowledge, concerning the more remote portions of the group of deposits to which, from its most accessible and representative exposure at the town of Grand Gulf, on the Mississippi River, I have given the name of "Grand Gulf Group."

So far as known at present, the "Vicksburg" group of marine marls and limestones, containing only extinct forms of life and therefore according to usage accounted "Eocene," closes abruptly the Tertiary series of marine fossiliferous deposits, on the entire mainland border of the Gulf of Mexico, from Florida to the Rio Grande. In the portions lying near the main axis of the Mississippi trough, the uppermost strata of the Vicksburg rocks show, by the constant intercalation of laminated clays and lignite beds and seams with the marine deposits, that the sea was shallowing more and more; and the highest portions are everywhere in the State of Mississippi characterized by a great prevalence of gypsum seams, and are often strongly impregnated with magnesian salts, as well as with common and Glauber's salts. The same is true of the lower portions especially, of the overlying Grand Gulf rocks; so that throughout the region occupied by the latter, few well-waters obtained within them are fit for daily use, and many are strongly mineral.

At their lines of contact, the Vicksburg and Grand Gulf rocks consist almost throughout of lignito-gypseous, laminated clays, passing upward into more sandy materials: they are not sensibly unconformable in place; but while the Vicksburg rocks show at all long exposures a distinct southward dip of some three to five degrees, the position of the Grand Gulf strata can rarely be shown to be otherwise than nearly or quite horizontal on the average; although in many cases faults or subsidences have caused them to dip, sometimes quite steeply, in almost any direction. They, however, lie high on the hill-tops between the towns of Vicksburg and Grand Gulf, and disappear at the water's edge near the Louisiana line, under the gravel beds of the Stratified Drift.

The latter is found directly capping, almost everywhere, the claystones and sandstones that characterize the highest part of the Grand Gulf group. Clearly, the Grand Gulf rocks alone represent, on the northern border of the Gulf, the entire time and space intervening between the Vicksburg epoch of the Eocene, and the Stratified Drift. Their total thickness does not exceed, if indeed it reaches, 250 feet. In the absence of deep borings on the Grand Gulf territory, this can be best observed on the northern edge of the formation, where it forms high ridges, from which there is an abrupt descent, northward, into the level prairie country of the Vicksburg territory.

From these rocky hills, which form sharp ridges diagonally across the States of Mississippi and Louisiana, and a portion of Texas, and which present even in small profiles an indefinite variety of more or less laminated claystones, clay-sandstones, or sometimes siliceous sandstones, there is a gradual descent southward, and a gradual increase of clayeyness and decrease of hardness, until, in the seaward portions of the formation, we find chiefly stiff, blue or green, and more or less massy clays. In these, at a certain level, there occurs a stratum copiously traversed by calcareous seams; and smaller ones occur at higher levels. In one such outcrop, on Pearl River, I found the only vestige of a zoögene fossil thus far seen in the entire formation; it is recognized by Professor Marsh as a fragment of a turtle shell. Apart from this, my most patient search, in hundreds of localities, has failed to produce any definite fossil form; even the leaves associated with the lignite seams being so ill preserved as to be unrecognizable.

While in Mississippi and Louisiana the calcareous facies is altogether exceptional and local, a few square miles of black prairie (Anacoco Prairie) in western Louisiana being its only striking manifestation east of the Sabine, it seems to become almost predominant in middle and southern Texas. The black calcareous prairies of that portion of Texas lie in bands sensibly parallel to the coast, each band differing somewhat in character from the rest, on account of its soils being more or less directly derived from the materials of the underlying formations. These are successively, counting from the coast landward: the Port Hudson (Champlain), Grand Gulf, Vicksburg, Jackson (Tertiary), and finally the Upper Cretaceous beds. This state of facts, my knowledge of which was until lately based only on scattered data gathered here and there, has received detailed confirmation from the observations made by Dr. R. H. Loughridge in 1879, on a reconnoissance of the State made in connection with the agricultural investigations of the Census.

It is thus placed beyond doubt that the Grand Gulf rocks form a continuous belt, from the Perdido River on the western

line of Florida (where according to Dr. Smith the Vicksburg rocks reach the coast) to the Rio Grande; attaining a width of a little over a hundred miles in the axis of the Mississippi trough, southward of Vicksburg, and thence narrowing rapidly to an average width of forty miles in Texas, and crossing the Rio Grande with an approximate width of 150 miles. What becomes of it beyond the latter line, is a matter of conjecture.

Of the sweep of about 900 miles thus outlined as the known extent of this formation, about 400 may be considered as having been examined sufficiently in detail to prove the absence of marine fossils from the formation; the portion so examined embracing, moreover, its widest part and fully two-thirds of the area of outcrop.

I have heretofore (this Journal, Dec., 1871) remarked that such absolute dearth of fossils in a formation whose materials are so well adapted to their preservation, staggers belief; and that I interpret the calcareous seams and concretions, found in some portions of the formation, as derived from the long-continued maceration of an apparently copious fauna; as is exemplified in the Quaternary beds of Côte Blanche on the Louisiana coast, and notoriously in the limestones of the coral reefs.

But even upon this basis two points confront us in the discussion of the relations of the formation to the sea: the great rarity of the calcareous feature in the main body of the formation; and the utterly "unmarine" character of the materials generally, in the constant recurrence of the lignito-gypseous facies.

The first objection disappears, as just stated, in the south Texan portion of the area. Curiously enough, precisely the same thing happens in the case of the Quaternary strata of the Texan coast, whose direct connection with the "Port Hudson" strata of Mississippi and Louisiana is indisputable. Specimens collected by Dr. Loughridge on the coast at Port Lavaca, and according to him fairly representative of the general facies of the shore in that region, show that the subordinate feature of the fresh-water limestone ledges seen on the Louisiana coast, has here become quite prevalent. But here, also, fossils are very scarce at least, for he was unable to find a single recognizable form at any of the outcrops examined by him. It would thus seem as though we were driven to account for the same state of things in the Quaternary as well as in the later Tertiary period—the absence of marine deposits and fossils, where on ordinary grounds of probability we should expect to find them; and their replacement by fresh- or brackish-water deposits, with fossils macerated to unrecognizability.

To complement this statement of facts, while unable to find

any definite data to show the geological features of the region beyond the Rio Grande, I call attention to the fact that the edge of the Mexican plateau approaches the coast most closely to landward of Vera Cruz. At that place, the castle of San Juan De Ulloa stands on a rock which, from specimens brought home by soldiers from the Mexican war, I then understood to be a freshwater limestone, full of helices, or shells resembling them. If there be any more definite data extant on this point, I should be glad to have them pointed out. It seems almost incredible that so obvious a feature of a seaport so frequently visited by Americans should not have been better observed, even accidentally.

The geology of Yucatan is involved in equal obscurity. The casual statements made as to the nature of the rocks by travelers, are too indefinite to afford any clue upon which conclusions might safely be based.

As to Cuba and the rest of the Antilles, we do know that their shores are lined with marine fossiliferous Tertiaries, much disturbed by the upheavals that have occurred. We even have descriptions, and quite a long list of names, of fossils found in these formations. But on the one hand, the English observers have taken the futile pains of comparing these beds with European Tertiaries only; while Mr. Gabb, true to the time-honored idea of making as many distinct species as possible, has in his descriptions of the Tertiaries of Santo Domingo given us the impression of the creation of a new fauna specially for that island, with scarcely an attempt to identify the variations of forms there found, with those already known from the other Tertiaries of the Gulf border. Moreover, the tendency of most observers to pass lightly over the unconformable, difficult deposits of the Quaternary, in which no glory can be gained by describing and naming new species, has left us with but a faint idea even as to the presence or absence of such beds on the Antilles. I shall therefore not attempt the unpromising task of a discussion and comparison of what is known of their geology, with the known facts on the mainland of the United States.

How are the latter to be reconciled with the now well-ascertained great depth of the Yucatan Channel, and the at least not inconsiderable depth of the Straits of Florida? It seems scarcely possible to assume that both of these have been formed *de novo* at the end of the Tertiary period; nor even that the depth of the Yucatan Channel could have been so materially less since the Eocene time, as to allow of the freshening of "Sigsbee Deep" by the influx, whether of the regular drainage of the Continent, or of the contents of the receding great lakes of the plains. But the matter assumes

a different aspect when viewed by the light now afforded by our knowledge of the configuration of the bottom of the Gulf, and of the oscillations of level to which at least its northern shore, and especially the central portion of the Mississippi Valley, have been subject in Tertiary and Quaternary times.

I cannot but express my regret that the latter portion of these data should thus far rest almost alone upon my personal observations and conclusions. It seems to me that as the only ocean basin not separated from the central part of the North American Continent by areas of disturbance and mountain-making, the Gulf of Mexico deserves first and chief attention, as the reference plane from which the oscillations of that central portion must be measured; while its shores are the nilometers upon which those movements can alone be found recorded. It would seem as though the reading and exact understanding of that record should have been the first thing to be done in attempting to unravel the Tertiary and Quaternary history of the country lying between the Alleghenies and the Rocky Mountains; just as the measurement of a base line is the first in a geodetic survey. The stratified drift of the South alone renders intelligible the succession of events that must have occurred at the North; it is only on the shores of the Gulf, that the question whether the Glacial epoch of the interior was one of elevation or of depression, together with the measure of these, can be finally determined. I have vainly sought for assistance in this wide and important field, until quite lately, when the explorations of Smith and Loughridge, under the auspices of the United States Census, have furnished important additional data.

The state of the evidence regarding these oscillations may be thus summarized: A comparatively rapid upward movement of the bottom of the Mississippi trough during early Tertiary time, is conclusively shown by the rapid decrease of the depth of the Mississippi embayment, which from its head near Cairo to about the mouth of the Arkansas, is filled with lignitiferous clays with only here and there a small marine estuarian deposit; except that in the State of Arkansas, a residuary basin of the old (Cretaceous) trough retained deep-sea features until the beginning of the "Jackson" epoch. The latter, with its abundant marine fauna, headed by the great Zeuglodon, was evidently deposited on a comparatively steep slope forming the southern edge of the plateau that existed in the upper portion of the embayment; yet it also consists, in the main, of clayey materials largely intermixed with lignito-gypseous beds. The succeeding "Vicksburg" stage is more of a deep-sea character, and its inconsiderable thickness in Mississippi and Louisiana speaks of a short duration of the epoch, at the end of which the lignito-gypseous feature again appears.

About that time, as E. A. Smith's late observations show, the Peninsula of Florida emerged from the water, apparently in the prolongation of the upheaval which traverses the State of Georgia from Atlanta to its southeast corner, forming the great "divide" between the rivers flowing directly to the Atlantic, and those tributary to the Gulf. This axis of upheaval, I am informed by Dr. Loughridge, is marked by numerous and very long trap dykes, running parallel to it in the metamorphic region of the State. As Dr. Smith has observed, there is a distinct ridge or "back-bone" of Florida, formed of the Orbitoides limestone, that does not lose itself entirely until the Everglades are reached. On the Florida shore, the Vicksburg rock is mostly covered to a greater or less depth by the Quaternary coralline rock, though outcropping at Tampa and a few other points.

Subsequent to this upheaval, the Miocene and Pliocene beds were deposited on the Atlantic side of the peninsula, as they were on the rest of the Atlantic coast. Meanwhile, what happened on the Gulf side?

As we have seen, the Grand Gulf beds were being deposited during that time, or a part thereof, in the axis of the Mississippi trough, and all around the Texas shore to the Rio Grande, and doubtless beyond. Toward the east, these beds "run out" on or about the Perdido River, on the line between Alabama and Florida.

A glance at the map of the Gulf soundings will show that this places the western line of the outcrop of the Vicksburg rocks exactly in the prolongation of the edge of the great submarine border plateau outlined by the "100-fathom line," from which there is such a sudden descent, all around the Gulf, into deep water.

It may be premature to infer from this coincidence, that if the Gulf shores should be elevated to the extent of 600 feet all around, we should find it lined with a wall of "Vicksburg" limestones. But however that may be, the existence of this great shelf furnishes, as it seems to me, an explanation of the "Grand Gulf" rocks on the mainland.

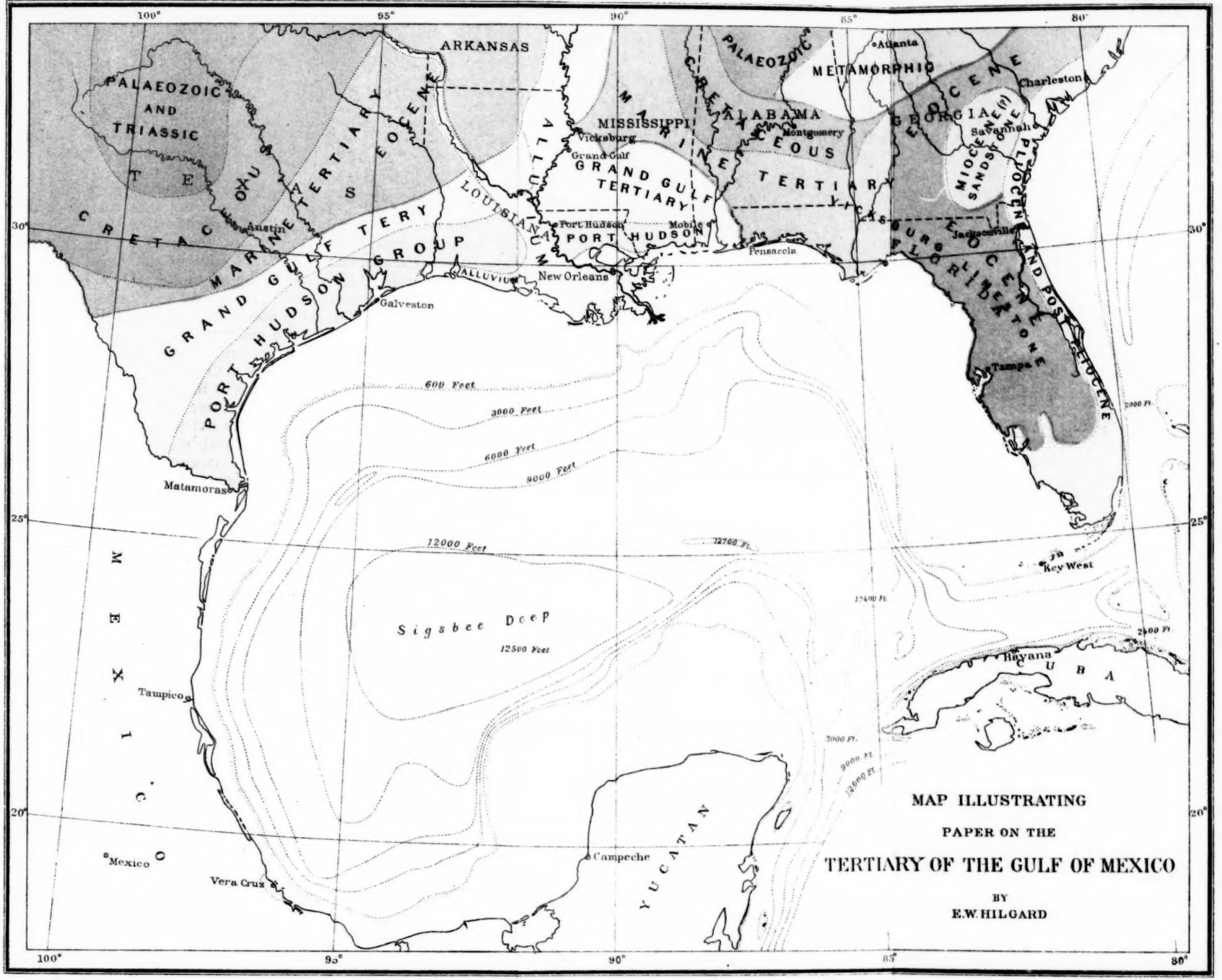
I take it for granted that the oscillations in the axis of the Mississippi Valley are proven to have been greater than on either side of the same; in other words, that it is, and has been, an axis of weakness and disturbance. As to the extent of its vertical movements in later Tertiary and Quaternary times, I have elsewhere shown that it cannot have been less than 900 feet between the time at which the great drift floods carried the northern pebbles to the Gulf shore, and that at which the loess of the Mississippi Valley was deposited. For we find the drift pebbles at a depth of 450 feet *below* the

waters of the Gulf, in the deep wells of Calcasieu; and the lœss lies at a similar height *above* the sea-level, not many miles above the head of the Mississippi Delta.

The inference is irresistible, that the upward movement of the Tertiary period continued up to the end of the Glacial epoch, whose gravel could not be carried far beyond the shores of the Gulf. It is clear, also, that even a minimum elevation of 450 feet, so far proven, would convert the Gulf border, to the edge of the 100-fathom line, into a region of shallows, whose waters would be kept perceptibly freshened by the continental drainage, especially in the axis of the Mississippi Valley, even in the present condition of the straits of Yucatan and Florida. If, however, we suppose the bottom of the latter to have participated in the elevation to a greater or less extent, sensibly lessening the oceanic circulation, the freshening of the border waters may readily be supposed to have been such as to render very precarious the existence of either a marine or fresh-water fauna; thus accounting for the remarkable dearth of fossil forms in the Grand Gulf strata. An occasional cessation of the movement, or other local cause, might for a time allow of the existence of limited areas of abundant life, such as are indicated by the subordinate calcare ous basins with, presumably, a macerated fauna. That these indications should increase as we approach the Yucatan channel, that is, along the ancient coast of Texas, is to be expected; and it may be fairly presumed, that, farther to the south, near Vera Cruz and beyond, we shall hereafter find the purely marine equivalents of the Grand Gulf rocks. That these rocks should have an exceptional character, that of coarse sandstones, near the axis of oscillation, is intelligible enough. It appears, however, that the sandstone character, which in Mississippi disappears about half way across the State, continues in Texas as far south as Indianola, and probably even to the Rio Grande, where, as previously mentioned, the formation seems to widen out even more than is the case in Mississippi. It would thus appear that Texas has participated, far more than Alabama, in the oscillations of the Mississippi Valley.

It should not be forgotten that in the latter, we find the Grand Gulf rocks, still capped by drift beds, at elevations of at least 500 feet above the Gulf. During the highest elevation of the Glacial epoch, therefore, they must have risen to over 900 feet above the sea, and in the reverse movement, of the Champlain epoch, they were again covered by the lœss and surface loams, to be re-elevated during the "Terrace" period of erosion, by which the present channel of the Mississippi River was formed.

The map of soundings exhibits very strikingly the analogy



MAP ILLUSTRATING

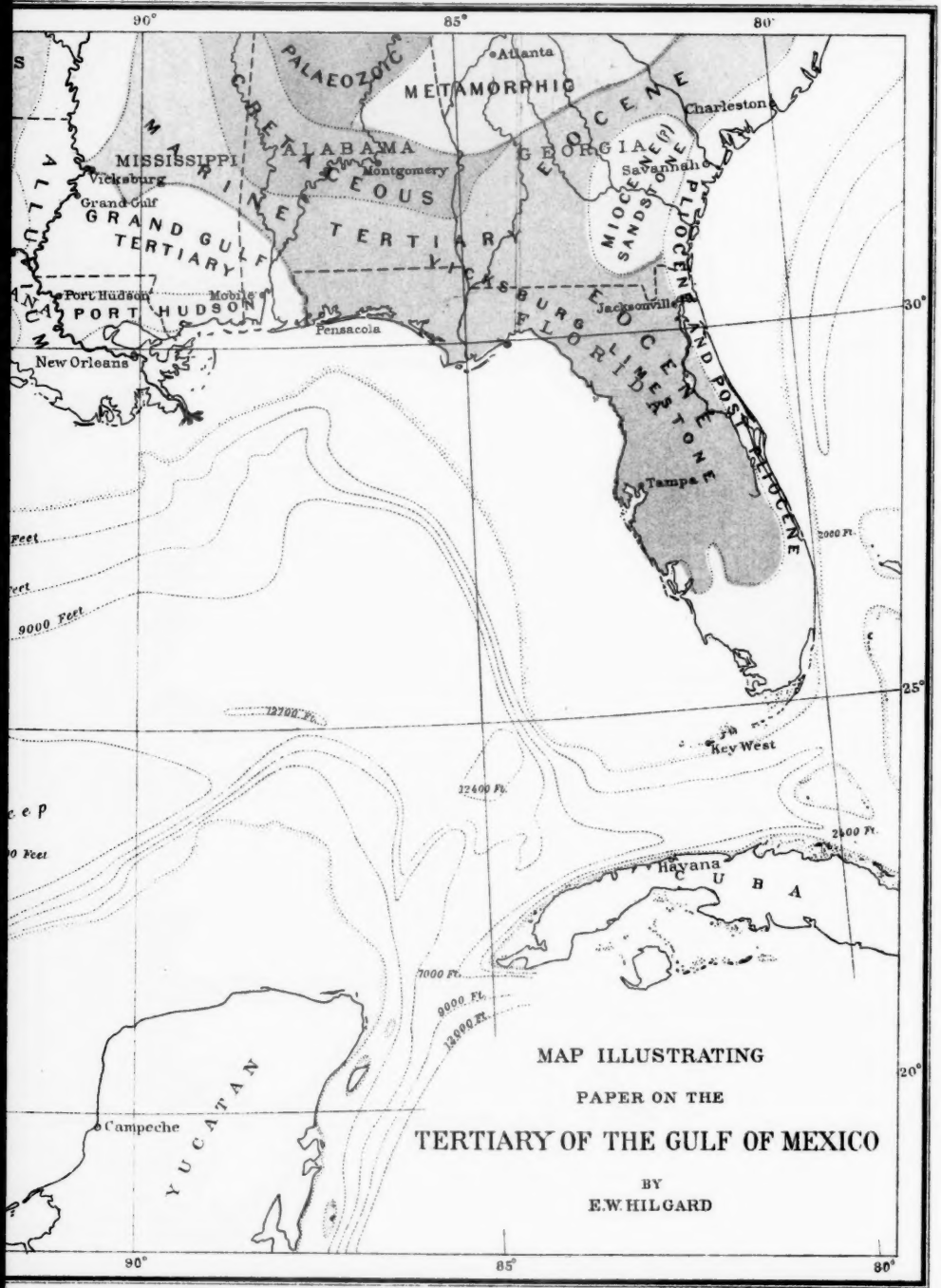
PAPER ON THE

TERTIARY OF THE GULF OF MEXICO

BY

E.W. HILGARD

Julius Bien, lith.



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of the relation of the two peninsulas of Florida and Yucatan to the Gulf Stream on the one hand, and the basin of the Gulf on the other. The eastern shores of both fall off steeply into deep water, while the gulfward shores are bordered by the shelf, 100 to 130 miles in width, which breaks off into deep water at the 100-fathom line. It would thus seem a priori probable, that both peninsulas were elevated at the same time and to a somewhat similar extent as regards their lowlands; and if so, this event cannot but have exerted a considerable influence in diminishing the volume of the Gulf Stream passing inside of Cuba, and in greatly restraining the peripheric Gulf current. Such events could not have failed to exert some influence upon the climate of the regions concerned, as well as upon the nature of the Gulf-border deposits.

Cannot something be done toward a prompt solution of this interesting problem in American Geology, upon which depend so many other mooted questions of first importance? A single season's yachting excursion along the shores of Mexico would, under the hands of a well-posted observer, be amply sufficient to settle all the main points. Even a few specimens of rock from prominent points might go far toward the elucidation. But any such exploration should be made, not with a view to the discovery and naming of new fossils, but with that of working from the base-line of the well-observed facts and regions toward those yet to be observed, and of unifying that which of necessity must have been evolved as a unit. That in order to accomplish this end, the weary catalogue of spurious species that now encumber our lists of Tertiary shells, must be thoroughly revised from the present biological point of view, is unfortunately true. Nowhere would a richer field reward the labors of the faithful worker. The *time* for this has certainly come—but where is the *man?*

ART. XIII.—*On Dufrenite from Rockbridge County, Va.;* by J. L. CAMPBELL.

DURING the summer of 1875, a number of specimens of iron ores from the Blue Ridge range in Rockbridge County, Va., were brought to my office for examination. One of these at once arrested my attention by its peculiar structure, color and luster. It had been taken from the mine in which it occurs partly in the form of irregular nodules, and partly as incrustations on the surface of an underlying bed of limonite. When broken open, the newly exposed surface showed a radiated, coarsely fibrous structure, with a rather dull silky luster, and a dark greenish brown (almost black) color. Where the surfaces

of the incrustations and nodules had been long exposed to the weather, the fibrous crystals had become changed in color to a yellowish brown, so as to resemble in general appearance fibrous limonite—the original structure being preserved.

The unaltered part of the mineral reduced to fine powder was of a light yellowish green color. When heated in a closed tube, it gave off water freely; and small fragments, heated to redness for a short time, assumed a bright reddish chestnut-brown color when cold. Before the blowpipe, it fused readily to black magnetic beads. With the borax bead the reactions of iron were well marked, with some indications of manganese. The mineral dissolved readily in hot hydrochloric acid. Tests applied to the solution indicated the presence of ferric oxide in abundance, and ferrous oxide in smaller quantities; while reactions of phosphoric acid were very decided.

A subsequent analysis of a choice specimen gave the following results: Specific gravity, 3·382; hardness, about 4:

Phosphoric acid (as pentoxide)	31·761
Ferrous oxide	6·144
Ferric oxide	50·845
Alumina	0·212
Manganous oxide	0·403
Lime	1·124
Magnesia	0·762
Water lost at red heat	8·531
Insoluble silica—very fine sand	0·115
	99·897

Some samples more recently tested left but a trace of silica when dissolved in hydrochloric acid, while others gave less lime and magnesia, and more alumina than the foregoing analysis indicates. Still, there is no reason to doubt that the great body of the mineral mass is "dufrenite," which hitherto seems rarely to have given identical results in the hands of any two analysts.

Geological position.—On visiting the locality where the dufrenite is found, it was ascertained to be about ten (10) miles east of Lexington, Va., near the crest of what is locally known as "South Mountain"—one of the many primordial broken ridges that skirt the northwestern base of the main Blue Ridge. It is in the ferriferous bed of shales and shaly sandstones that here constitutes the upper member of the primordial or Potsdam group. Its position will be readily understood by reference to a profile section of the Blue Ridge and Great Valley, published in this Journal for July, 1879, vol. xviii, page 19. That section cuts the range only a few miles to the southeast of Irish Creek, while the bed of dufrenite is a little to the northeast of the same stream. But if the stratum on the section marked 1*g* be conceived to extend nearly to the top of

that marked 1*f*, its upper limit would very well indicate the geological locality of the mineral deposit. The strata here, however, have a much more moderate dip than at the point cut by the section.

A rude shaft or pit was found to have been sunk through the beds of dufrenite into a mass of underlying limonite to a depth of ten or twelve feet. The irregular bed of dufrenite, made up of irregular nodular masses, having from one to eight inches of diameter, and incrustations of like varying thickness, lies near the surface of the ground, and has an average depth of ten or twelve inches, as far as could be determined in the presence of a considerable caving in of the old shaft.

This mineral had been thrown aside in mining as being of doubtful character, in the eyes of those who were exploring for iron ores, and several tons had been accumulated near the mouth of the opening; but since I first called attention to its true character, and although the locality is difficult of access, the whole of what was thrown out by the miners has been carried away and sent to different public institutions and to dealers in minerals.

This is, perhaps, the most extensive deposit of this mineral yet discovered in the United States.

Washington and Lee University, Lexington, Va., May, 1881.

ART. XIV.—*Turquois of New Mexico;* by B. SILLIMAN.*

THE existence of turquois, a comparatively rare gem, in New Mexico, is a fact long known. The chief locality is at Mt. Chalchuitl, in Los Cerillos, about twenty-two miles southwest of the ancient town of Santa Fé, the capital of that territory. We are indebted to Professor Wm. P. Blake for our first detailed notice of this ancient mine, in an article published in the American Journal of Science† in 1857.

It was subsequently visited by Dr. Newberry who mentioned it in one of his reports, and also by others. I have lately had an opportunity of examining this very interesting locality, since it has been laid open in the old workings and thus rendered accessible to observation by the recent explorations of Mr. D. C. Hyde.

The Cerillos Mountains have recently come into notice from the partial, and as yet superficial, exploration of very numerous mineral veins which are found to intersect them, and which

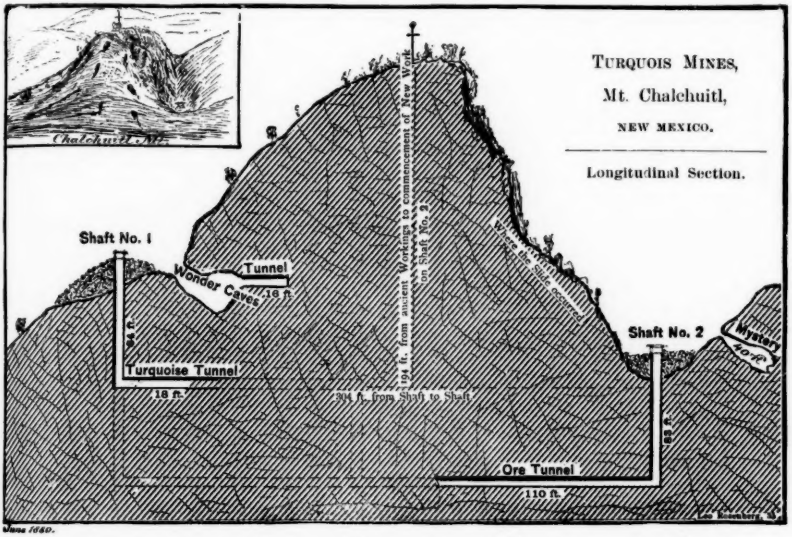
* Read before the American Association for the Advancement of Science, Boston, August, 1880.

† This Journal, 2d Ser., xxv, 27.

carry chiefly argentiferous galena, with some gray copper rich in silver, giving promise of mines of value when opened in depth. I have elsewhere spoken more particularly of these veins and of the rocks that contain them. These rocks are all eruptive rocks of the family of the augite trachytes, the kind which, the world over, carries the richest and most permanent ores of silver, with some gold. In the center of this district, which is not more than about six miles by four in extent, rises the dome of Mt. Chalchuitl (whose name the old Mexicans gave to the turquois, its much valued mineral), the summit of which is about 7,000 feet above tide, and is therefore almost exactly on a level with the Plaza of Santa Fé, across the valley of the river of that name, to the northeast. In the other direction this mountain has its drainage into the valley of the Galisteo, which forms the southern boundary of the Cerillos district. The age of eruption of these volcanic rocks is probably Tertiary. The rocks which form Mt. Chalchuitl are at once distinguished from those of the surrounding and associated ranges of the Cerillos by their white color and decomposed appearance, closely resembling tuff and kaolin, and giving evidence to the observer familiar with such phenomena of extensive and profound alteration; due, probably, to the escape through them, at this point, of heated vapor of water and perhaps of other vapors or gases, by the action of which the original crystalline structure of the mass has been completely decomposed or metamorphosed, with the production of new chemical compounds. Among these the turquois is the most conspicuous and important. In this yellowish-white and kaolin-like tufaceous rock the turquois is found in thin veinlets and little balls or concretions called "nuggets," covered with a crust of the nearly white tuff, which within consist generally, as seen on a cross fracture, of the less valued varieties of this gem, but occasionally afford fine sky-blue stones of higher value for ornamental purposes. Blue-green stains are seen in every direction among these decomposed rocks, but the turquois in masses of any commercial value is extremely rare, and many tons of the rock may be broken without finding a single stone which a jeweler, or virtuoso would value as a gem.

The observer is deeply impressed on inspecting this locality with the enormous amount of labor which in ancient times has been expended here. The waste or debris excavated in the former workings covers an area, which the local surveyor assured me extends by his measurement over at least twenty acres. On the slopes and sides of the great piles of rubbish are growing large cedars and pines, the age of which—judging from their size and slowness of growth in this very dry region

—must be reckoned by centuries. It is well known that in 1680 a large section of the mountain suddenly fell in from the undermining of the mass by the Indian miners, killing a considerable number, and that this accident was the immediate cause of the uprising of the Pueblos and the expulsion of the Spaniards in that year, just two centuries since.



The accompanying vertical section of the mountain from east to west will give a good idea of the old workings, and of the shafts and tunnels projected and partly carried out by Mr. Hyde. The irregular openings, named by Mr. Hyde "wonder caves" and the "mystery," are the work of the old miners, and the whole hillside from the flag-staff to the "mystery" was worked out by them also. It was this sharp slope of the mountain which fell. In these chambers, which have some extent of ramification, were found abundantly the fragments of their ancient pottery, with a few entire vessels, some of them of curious workmanship, ornamented in the style of color so familar in the Mexican pottery. Associated with these were numerous stone hammers, some to be held in the hand and others swung as sledges, fashioned with wedge-shaped edges and a groove for a handle. A hammer weighing over twenty pounds was found while I was at the Cerillos, to which the wyth was still attached, with its oak handle—the same scrub oak which is found growing abundantly on the hillsides—now quite well perserved after at least two centuries of entombment in this perfectly dry rock.

The stone used for these hammers is the hard and tough hornblende andesite, or propylite, which forms the Cerro d'Oro and other Cerillos hills. With these rude tools and without iron and steel, using fire in place of explosives, these patient old workers managed to break down and remove the incredible masses of these tufaceous rocks which form the mounds already described.

That considerable quantities of the turquois were obtained can hardly be questioned. We know that the ancient Mexicans attached great value to this ornamental stone, as the Indians do to this day. The familiar tale of the gift of large and costly turquois by Montezuma to Cortez for the Spanish crown, as narrated by Clavigero in his history of Mexico, is evidence of this high estimation. It is not known that any other locality in America has furnished turquois in any quantity—the only other place thus far reported outside of Los Cerillos being that near Columbus District in Nevada, discovered by Mr. J. E. Clayton; and this is not yet worked.

The origin of the turquois of Los Cerillos in view of late observations is not doubtful. Chemically it is a hydrous aluminum phosphate. Its blue color is due to a variable quantity of copper oxide derived from associated rocks. I find that the Cerillos turquois contains 3·81 per cent of this metal. Neglecting this constituent, the formula for turquois requires: Phosphoric acid 32·6, alumina 47·0, water 20·5=100·?.

Evidently the decomposition of the feldspar of the trachyte furnishes the alumina, while the apatite, or phosphate of lime, which the microscope detects in thin sections of the Cerillos rock, furnished the phosphoric acid. A little copper ore is diffused as a constituent of the veins of this region, and hence the color which that metal imparts.

The inspection of thin sections of the turquois by the microscope, with a high power, detects that the seemingly homogeneous mass of this compact and non-crystalline mineral consists of very minute scales, nearly colorless, having an aggregate polarization, and showing a few particles of iron oxide.

The rocks in which the turquois occurs are seen, by the aid of the microscope and polarized light, in thin sections, to be plainly only the ruins, as it were, of crystalline trachytes; they show fragments of feldspar crystals, decomposed in part into a white kaolin-like substance, with mica, slag and glassy grains, and quartz with large fluidal enclosures, looking like a secondary product. There is considerable diversity in aspect, but they may all be classed as trachyte-tuffs and are doubtless merely the result of decomposition, as already indicated, of the crystalline rocks of the district along the line of volcanic fissures. In fact there are, in a northerly direction, other places,

one of them at Bonanza City, probably two or three miles distant, where the same evidence of decomposition is found, and in the rocks at this place I found also the turquois in forms not to be distinguished from those of the old mine. Mr. Hyde has shown me lately in New York a large number of the Cerillos turquois polished, one of huge size; and among them a few of good color and worthy of consideration as gems, some of them an inch in length and quite thick, but they are not of faultless beauty.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Free Fluorine in Fluor Spar.*—The cause of the peculiar odor possessed by the dark violet fluor spar of Wölsendorf has been much discussed. Schafhäutl ascribed it to the presence of calcium hypochlorite, Schrötter to ozone, Schönbein to antozone, and Wyrouboff to a hydrocarbon. Loew, noticing the similarity of the odor on freshly fractured surfaces to that of chlorine, concluded that it was due to the presence of fluorine formed by the dissociation of some foreign fluoride present in minute quantity. The ozone theory was given up by Schrötter when he found that the odor was not destroyed by a heat of 310°. Moreover, he showed an alteration in this odor when the mineral was ground with potassium hydrate solution, and proved that an odor resembling that of sulphur chloride was produced when it was rubbed in a mortar with sulphur. Chlorine was separated from sodium chloride by it and iodine from potassium iodide. To test his fluorine hypothesis, Loew ground a kilogram of Wölsendorf fluor spar with water containing ammonia, using small portions at a time, the filtrate and wash-waters from the earlier being used with the later quantities. The last filtrate was mixed with sodium carbonate, evaporated, the residue treated in a platinum capsule with sulphuric acid, and, covered with a watch glass, kept at 40° to 50° for a long time. On examining the glass it was found to be very considerably corroded. Since fluor spar is not entirely insoluble in water, the experiment was repeated, using the inodorous mineral. The result was so exceedingly feeble as to dispose entirely of this objection to the former result. Since these dark radiated varieties of fluorite contain cerium, the author thinks a ceric fluoride is the source of the free fluorine, by dissociating into cerous fluoride and fluorine, analogous to the decomposition of manganese tetra-chloride at ordinary temperatures.—*Ber. Berl. Chem. Ges.*, xiv, 1144, May, 1881. G. F. B.

2. *On Arsenobenzene.*—Azo-benzene $C_6H_5N{=}NC_6H_5$, has long been known, and phosphobenzene $C_6H_5P{=}PC_6H_5$ has recently been discovered. The corresponding compound of arsenic, arseno-

benzene $C_6H_5As=AsC_6H_5$ has now been obtained by MICHAELIS and SCHULTZE. For this purpose phenyl-arsenous oxide C_6H_5AsO was acted upon in alcoholic solution by reducing agents, preferably phosphorous acid. No change takes place in the cold but on heating nearly to boiling the reaction takes place and the mass solidifies in crystals. On filtering, washing with hot alcohol and drying in a vacuum over sulphuric acid, the arsenobenzene is obtained pure, in the form of pale yellow needles, difficultly soluble in alcohol, insoluble in water and ether. Chloroform, carbon disulphide, and benzene dissolve it easily, but the solution resinifies readily. Beautiful crystals are obtained on cooling from solution in hot xylene. Chlorine unites with it directly to form phenyl-arsenous chloride. It fuses at 196° to a yellow liquid, and decomposes above this, evolving triphenylarsine and metallic arsenic. Phenyl-arsenous iodide when reduced gives arseno-iodo-benzene $C_6H_4IAs-AsIC_6H_5$. Naphthalene acts similarly, an arsenonaphthalene $C_{10}H_7As=AsC_{10}H_7$ being produced by the reduction of naphthyl-arsenous oxide by phosphorous acid.—*Ber. Berl. Chem. Ges.* xiv, 912, Apr., 1881. G. F. B.

3. *On the Transformation of Dextrose into Dextrin.*—Some years ago, MUSCULUS observed that when dextrose was dissolved in concentrated sulphuric acid, a new body was obtained which was probably a dextrin. The recent experiments of Gautier, have led Musculus in conjunction with MEYER, to re-examine this subject. Twenty grams of pure dextrose was melted in a calcium-chloride bath; after cooling thirty grams of concentrated sulphuric acid was added in four or five successive portions, the whole being stirred with a thermometer, the temperature being allowed to rise to 60° and the mixture to become brown. Eight hundred parts of absolute alcohol were then added, the solution filtered and allowed to stand for eight days. The abundant precipitate was collected on a filter and washed, first with cold and then with boiling absolute alcohol till all traces of acid were removed. It was then dried. In this way there were obtained ten grams—half the dextrose used—of a perfectly white amorphous powder, hygroscopic but not deliquescent. It contains alcohol not removable by drying over sulphuric acid for months or by a heat of 100°. By solution in water and distillation 9·3 per cent of alcohol was obtained. Heated to 110°, the alcohol evaporates and the remaining powder is extremely deliquescent. On analysis it gave numbers agreeing with the formula $C_{18}H_{28}O_{14}$. Hence the first powder was a combination of this with a molecule of alcohol, $C_{18}H_{28}O_{14}.C_2H_6O$, which requires 8·9 per cent of alcohol. This, when decomposed by water, the alcohol removed by evaporation and the residue dried over sulphuric acid, gives a body whose analysis agrees with the formula $C_6H_{10}O_5$. When therefore the alcohol in the above formula is replaced by water the formula becomes $C_{18}H_{28}O_{14}.H_2O$ or $(C_6H_{10}O_5)_3$. This hydrated body possesses all the physical, chemical and organoleptic properties of a dextrin. It is amorphous, yellowish, very soluble in water, of a

flat sweetish taste, is not colored by iodine, is precipitated by alcohol from its aqueous solution, reduces only very feebly Fehling's test, rotates to the right the plane of polarized light $[a]=+131$ to $+134°$, does not ferment with yeast, is not saccharified by diastase, is converted into dextrose by prolonged boiling with dilute sulphuric acid, and has the diffusibility of a dextrin, being nearest to the γ-dextrin of Musculus.—*Bull. Soc. Ch.*, II, xxxv, 368, Apr., 1881. G. F. B.

4. *On Pentathionic Acid.*—Lewes has satisfactorily established the existence of pentathionic acid. Continuous currents of hydrogen sulphide and sulphurous oxide gases were passed, according to Wackenroder's method, into distilled water, the former in slight excess, for seven hours, the mass heated on a water bath, filtered from sulphur and analyzed. Three separate methods gave in 10 c.c. 0·23, 0·227 and 0·226 of sulphur. On titrition, 1 c.c. neutralized 0·01457 gram K_2O, equal to 0·012 gram potassium; thus giving 2 : 4·55 for the ratio of K : S, and suggesting the presence of an acid having more sulphur than the tetrathionate. Having noticed that a partly neutralized solution decomposed only very slightly, Lewes added to a solution prepared as above, a weak solution of barium hydrate, sufficient to neutralize only half of it. On filtering after standing twenty-four hours, a clear solution was obtained which was placed in a vacuum over sulphuric acid. After 18 days a crop of fine needle-shaped crystals was obtained which proved on analysis to be barium tetrathionate. In a few days a second crop of crystals was obtained consisting of thin square plates mixed with a few oblong rectangular crystals, which gave on analysis numbers between those of tetra- and pentathionate, probably a double salt. A third crop of very small oblong rectangular crystals was obtained which gave on analysis numbers agreeing with the formula $BaS_5O_6(H_2O)_2$. The salt is soluble in cold water and if not too concentrated the solution may be boiled. The reactions of the solution are given. By the same process, three potassium salts of pentathionic acid were obtained; one in semi-opake, probably rhombic crystals $K_2S_5O_6(H_2O)_2$; another in small and apparently monoclinic crystals, having one molecule of water of crystallization; and a third in very small, short prisms, which is the anhydrous pentathionate $K_2S_5O_6$. These salts may be easily prepared as they are much more stable than the barium salt. They are distinguished from the corresponding tetrathionates by the fact that they give an immediate precipitate of sulphur on adding an alkali hydrate.—*J. Chem. Soc.*, xxxix, 68, March, 1881. G. F. B.

5. *Photographics: A Series of Lessons, accompanied by Notes, on all the Processes which are needful in the Art of Photography;* by Edw. L. Wilson. 8vo, pp. 352. Philadelphia, 1881.—Mr. Wilson has sought in this book to produce a hand-book for the professional as well as for the amateur photographer. The plan is somewhat novel. After giving in a clear and satisfactory way, on the upper half of the page, the matter culled from his own

experience, he prints in smaller type, on the lower half, quotations bearing directly on the subject in hand, and taken from the best authorities known. In this way the opinions of over two hundred authors have been secured to the reader. The science and the art of photography is given in twenty-seven lessons, each treating of one branch. The first of these on the treatment of the subject is an excellent discussion of the esthetic in photography, illustrated from the masters in art. Then follows the technique of the wet plate process in all its parts. The dry plate process follows this, and then some of the more recent phototype processes, and the book closes with some useful practical suggestions. The work appears to be a great success in its manner as well as its matter. It will certainly become the standard book on photography in this country. G. F. B.

6. *Conservation of Electricity.*—In a memoir by M. G. LIPPMANN, presented to the French Academy by M. Jamin, the author maintains that the quantity of matter and the quantity of energy are not the only magnitudes in nature which remain invariable; the quantity of electricity in the universe is also invariable. The distribution of electricity can change, but the quantity of free electricity never varies. The sum of the quantities of free electricity is invariable since the total variations of the charges is always equal to zero. Let x and y be two independent variables upon which the quantity of electricity which a body receives depends; x can be, for example, the potential which the body acquires, y its capacity, or a quantity proportional to the capacity. Let dm be the quantity of electricity received by a body when x is increased by dx and y by dy; one can then write $dm = \mathrm{P}dx + \mathrm{Q}dy$, in which P and Q are two functions of x and of y. The principle of the conservation of electricity is expressed by the condition that dm shall be an exact differential. Divide, for instance, any system in which an electrical phenomenon is produced, into two portions, A and B. Let a and b be the simultaneous variations of these two portions. In virtue of this principle of the Conservation of Electricity, we must have $a+b=0$. When A passes over a closed cycle, that is to say, when its final state corresponds to its initial one, $a=0$ and $b=0$. We can then write $\int dm=0$. In order that $\int dm$ may be zero for every closed cycle, it is necessary that dm shall be an exact differental, or $\frac{d\mathrm{P}}{dy}=\frac{d\mathrm{Q}}{dx}$. In this manner we can write the analytical expressions for the general principle of the Conservation of Electricity.—*Comptes Rendus*, No. 18, May 2, 1881. J. T.

7. *Inverse Electromotive force of the Voltaic arc.*—M. J. Jamin corroborates the statements of M. Le Roux in regard to the inverse electromotive force which arises from the carbon points of the electric lights. This electromotive force is nearly equivalent to that of ten to fifteen Bunsen elements. In obtaining, therefore, a light from a battery of thirty to forty Bunsen cells,

only twenty-five are useful in maintaining the light. Thus it is difficult to produce two or a greater number of arcs in the same continuous current, since it is necessary to overcome the inverse electromotive force of each light. This fact is an objection to the use of batteries, continuous current machines, secondary batteries like those of Planté or of Faure. The conditions, however, are very different with the use of alternate current dynamo-electric machines; for with a certain speed of alternation the effect of the inverse electromotive force is a minimum. The difference of temperature of the carbon points determines the strength of the inverse electromotive force, and when this difference of temperature tends to disappear as it does when alternate currents are employed, the inverse electromotive force is very much diminished.—*Comptes Rendus*, No. 18, May 2, 1881. J. T.

8. *Stellar Photography.*—In a letter addressed to M. A. Cornu, H. Draper relates that he has succeeded in photographing, after an exposure of one hundred and forty minutes, the stars in the nebula of Orion, which can be represented in size by the numbers 14·1, 14·2, 14·7, according to the scale of Poyson. Photography has thus secured images of stars nearly at the limit of visibility in a telescope of nine inches aperture. It seems, therefore, not improbable that stars which are invisible to the eye in a telescope of this size can be photographed.—*Comptes Rendus*, No. 16, April, 1881. J. T.

9. *Weather Warnings.*—Professor Balfour Stewart, in a lecture delivered at South Kensington, April 29, spoke of the probability that British magnetical weather may be followed after five or six days by corresponding meteorological weather. From a preliminary trial, Professor Stewart believes that it may be possible to forecast meteorological weather some five or six days by means of the variations of the magnetic elements.—*Nature*, May 5, 1881. J. T.

10. *Storing of Electricity.*—M. Faure has modified the secondary battery of Planté by coating the lead plates with a covering of minium. The sheets of lead are separately covered with minium and rolled together in a spiral with a layer of felt between, and are then placed in a vessel of sulphuric acid and water. When a current is passed into this cell the minium on one plate is reduced to metallic lead and on the other is oxidised to peroxide. When the cell is discharged this action is reversed. According to M. Reynier, one of these spiral cells weighing 75 kilograms can store up energy sufficient to furnish one horse power for an hour.—*Nature*, May 19, 1881. J. T.

II. Geology and Natural History.

1. *Sketch of the Geology of British Columbia;* by George M. Dawson, D.S., A.R.S.M., F.G.S.—British Columbia includes a certain portion of the length of the Cordillera region of the west coast of America, which may be described as consisting here of

four parallel mountain ranges running in a northwest and southeast bearing. Of these the southwestern is represented by Vancouver and the Queen Charlotte Islands, and may be referred to as the Vancouver Range; while the next, to the northeast, is the Coast or Cascade Range, a belt of mountainous country about 100 miles in width. This is succeeded by the interior plateau of British Columbia, relatively a depressed area, but with a height of 3000 to 3500 feet. To the northeast of this is the Golden Range, and beyond this the Rocky Mountains proper, forming the western margin of the great plains of the interior of the continent.

Tertiary rocks, which are probably of Miocene age, are found both on the coast and over the interior plateau. They consist on the coast of marine beds, generally littoral in character, which are capped, in the Queen Charlotte Islands, by volcanic rocks. The interior plateau has been a freshwater lake, in or on the margin of which, clays and sandstones, with occasional lignites, have been laid down. These are covered with very extensive volcanic accumulations, basaltic or tufaceous.

Cretaceous rocks from the age of the Upper and Lower Chalk to the Upper Neocomian, and representing the Chico and Shasta groups of California, occur on Vancouver and the Queen Charlotte Islands. Beds equivalent to the Chico group yield the bituminous coals of Nanaimo, while anthracite occurs in the somewhat older beds of the Queen Charlotte Islands. Within the Coast range the Cretaceous rocks are probably for the most part equivalent in age to the Upper Neocomian. The Cretaceous rocks are of great thickness, both on the coast and inland, and include extensive contemporaneous volcanic beds.

The pre-Cretaceous beds had been much disturbed and altered before the deposition of the Cretaceous, and their investigation is difficult. On Vancouver Island, beds probably Carboniferous in age include great masses of contemporaneous volcanic material, with limestones, and become altered to highly crystalline rocks resembling those parts of the Huronian of Eastern Canada. In the Queen Charlotte Islands these beds also probably occur; but an extensive calcareous argillite formation is there found, which is characterised by its fossils as Triassic.

The Coast Range is supposed to be built up chiefly of rocks like those of Vancouver Island, but still more highly altered, and appearing as gneisses, mica-shists, &c., while a persistent argillaceous and slaty zone is supposed to represent the Triassic argillites of the Queen Charlotte Islands.

The older rocks of the interior plateau are largely composed of quartzites and limestones; but still hold much contemporaneous volcanic matter, together with serpentine. Carboniferous fossils have been found in the limestones in a number of places. The Triassic is also represented in some places by great contemporaneous volcanic deposits with limestones.

In the Golden Range, the conditions found in the Coast Range are supposed to be repeated; but it is probable that there are

here also extensive areas of Archæan rocks. Some small areas of ancient crystalline rocks, supposed to be of this age, have already been discovered.

The Rocky Mountain Range consists of limestones with quartzites and shaly beds, dolomites and red sandstones. The latter have been observed near the 49th parallel, and are supposed to be Triassic in age. The limestones are, for the most part, Carboniferous and Devonian, and no fossils have yet been discovered indicating a greater age than the last-named period. On the 49th parallel, however, the series is supposed to extend down to the Cambrian, and compares closely with the sections of the region east of the Wahsatch, on the 40th parallel, given by Clarence King. Volcanic material is still present in the Carboniferous rocks on the 49th parallel.

The oldest land is that of the Golden Range, and the Carboniferous deposits laid down east and west of this barrier differ widely in character. The Carboniferous *closed with a disturbance* which shut the sea out from a great area east of the Gold Range, in which the red gypsiferous and saline beds of the Jura-trias were formed. In the Peace River region, however, marine Triassic beds are found on both sides of the Rocky Mountains.

A great disturbance, producing the Sierra Nevada and Vancouver ranges, closed the Triassic and Jurassic period. The shore line of the Pacific of the Cretaceous in British Columbia lay east of the Coast Range, and the sea communicated by the Peace River region with the Cretaceous Mediterranean of the great plains.

No Eocene deposits have been found in the province. The Miocene of the interior plateau is probably homologous with King's Pah-Ute lake of the 40th parallel Miocene. In the Pliocene the country appears to have stood higher above the sea-level than at present, and during this time the fiords of the coast were probably worn out.—*Proc. Geol. Soc. London*, 1881.

2. *Caribbean Miocene fossils.*—A memoir, on Miocene fossils of Sapote, Costa Rica, and a few from Gatun, on the Panama Railroad, by the late W. M. Gabb, is published in Part IV of vol. viii (2d Ser.) of the Journal of the Academy of Natural Sciences. A number of the species are identical with Miocene species of San Domingo.

3. *Report of the State Geologist of New Jersey for the year* 1880.—Professor GEORGE H. COOK, the State Geologist, devoted a considerable part of his last report to a discussion of the relations of the soils of the various regions of the State to the accompanying rocks, which subject was illustrated by a colored map of the State. The Report for 1880 contains an extended account of the Glacial drift over New Jersey, including the facts as to the course of the terminal moraine across the State, terraces along valleys, and those as to other gravel and sand deposits, chiefly in Southern New Jersey, which are regarded as of pre-glacial origin.

He then shows that on the Passaic River, southwest of Patterson, the waters of the flooded river were spread into a lake 30 by 6 or 8 miles in its diameters and 200 feet deep, owing to the confining ridges of trap on the east and south. One of the most remarkable bowlder deposits in the southern extremity of the State is in Cape May County about Dennisville, especially between Dennis Creek and Cumberland County. The bowlders have worn but not rounded edges, and have not been observed to have glacial markings. The largest, in North Dennisville, measured 14 feet in length and averaged 11 by 17 inches in its other dimensions; another is 7 feet in diameter. It is suggested that they may have come on floating ice down the Delaware when the waters stood 60 feet above their present level.

At Paterson a well has been sunk 2100 feet in the Red Sandstone (Triassic), proving thus that the thickness of the rock exceeds this amount. It obtained water at 1120 and 2050 feet; and that at the latter depth (which ascended to within 30 feet of the surface) was saline, it containing about half as much common salt as the water of the ocean, and more of chlorides of potassium, calcium and magnesium. The total amount of solid matter per gallon was 929·46 grains.

4. *Geological Survey of Pennsylvania.*—The legislature of Pennsylvania has passed, and the Governor has approved, a bill appropriating $125,000 to the State Geological Survey under the direction of Professor J. P. Lesley. This insures the completion of this great work in 1883, ten years from its commencement, the whole expense having been $445,000, besides the printing.

The Geology of the Oil Regions of Warren, Venango, Clarion and Butler Counties; by JOHN F. CARLL, Report III of the Geological Survey of Pennsylvania. 482 pp., 8vo.—Mr. Carll's report shows careful and judicious observation in all its chapters, whether treating of geology or the characteristics of the oil-producing regions; the condition of the oil deposits, the origin of the oil and of the associated beds; or of the topography, drainage, and drift phenomena of the districts. In addition, it gives an account of oil-well exploration, machinery and tools. In these and all its subjects, it is well illustrated by drawings and sections. It is a work of great practical and scientific value.

5. *Annual Report of the Bureau of Statistics and Geology of Indiana for* 1880.—In Indiana, the duties of State Geologist were, in 1879, transferred to the Bureau of Statistics and Geology, of which Professor John Collett, an excellent geologist, is the Chief. It is creditable to the intelligence of that State, that their law requires that the head of that Bureau shall be an expert in the sciences of geology and chemistry. Professor Collett has published two annual reports, the last of which contains about fifty pages on geology with plates of fossils. J. M.

6. *Illustrations of the Earth's Surface: Glaciers;* by N. S. SHALER, Professor of Palæontology, and WM. M. DAVIS, Instruc-

tor in Geology, in Harvard University; 196 pp., large 4to, with 25 plates. Boston, 1881. (James R. Osgood & Co.)—The plan of the series of which this volume is the first is to present illustrations of prominent subjects in geology—Glaciers, Mountains, Volcanoes, Earthquakes, etc., as far as possible from photographs, and accompanying text giving "a connected idea of the more essential facts and theories that belong to each subject." The volume which has been issued, on Glaciers, is exceedingly well adapted for its purpose. Its illustrations represent some of the most characteristic of glaciers, with a degree of perfection scarcely exceeded by the photograph, and on a scale of magnitude, owing to the large 4to size, that exhibits all details in perfection. Among them are the Glacier des Bossons, de Talèfre from the Jardin, the Aletsch in several views, du Géant, and others, in the Alps, with some from the Himalaya, Norway, etc. Besides these, several plates are devoted to other Glacial phenomena, and some to those of the Glacial era, especially the American. The subjects are happily chosen for instructiveness, and the beauty of the plates is remarkable. The text gives an excellent general review of the subject of glaciers modern and ancient, with many important descriptive details. It discusses Croll's theory of the origin of glacial cold, with criticisms, and also other opinions on the subject; treats of the movement of glaciers; of glacier deposits; of soils from glaciers; of the blue and yellow clays—attributing the latter to oxidation since deposition, as done by Van den Brœck in the work mentioned beyond. The volume is a very valuable one for both instructor and student.

7. *The Trilobite: New and Old Evidence Relating to its Organization;* by C. D. Walcott. Bull. Comp. Zool., vol. viii, No. 10. —Mr. Walcott here presents the results of his remarkable dissections of Trilobites, with full illustrations on six plates. The species examined were *Ceraurus pleurexanthemus*, *Calymene senaria*, and *Asaphus platycephalus*. The results show, beyond question, the existence of a series of jointed organs about the mouth, and appear to indicate a continued series down the thorax and into the pygidium, besides exhibiting remains of ambiguous organs, looking as if spiral, and supposed by the author to be branchial in relations. A "restoration" of *Calymene senaria* is given on plate vi. The series of legs in this restoration looks very doubtful, for, if so distinct in the animal, it seems to be incomprehensible that such dissections should have been needed for their discovery. A series of distinct ambulatory legs on a large Trilobite should have been large and stout, and could hardly have escaped preservation in the form of large and stout limbs. It may be that the supposed joints of the legs of the thorax and posterior extremity, which have the appearance of having been thin or membranous, are merely subdivided and thickened portions of the outer ventral shell, which served as attachments for thin membranous articulated appendages such as have hitherto been attributed to Trilobites. J. D. D.

8. *Geological Survey of Alabama: Report of progress for* 1879 *and* 1880; by EUGENE A. SMITH, Ph.D., State Geologist; 158 pp., 8vo.—This report contains a detailed description of the coal-measures of the Warrior Coal Field, and is accompanied by a geological map of the region.

9. *The Felsites and their associated rocks north of Boston;* by J. S. DILLER. Bulletin of the Museum of Comparative Zoology at Harvard College, vol. vii, (Geological Series, vol. i, pp. 165 to 180, 8vo).—Prof. Diller treats of the physical and other characters of the felsitic rocks, including felsites and conglomerates, of Medford, Malden, Melrose, Wakefield, Saugus and Lynn, in Eastern Massachusetts, and of some of the adjoining rocks. He arrives at the conclusion that the felsites are eruptive rocks. He gives for the order of age for the rocks referred to as eruptive: granite, felsyte, dioryte, and diabase and melaphyre.

10. *Mémoire sur les Phénomènes d'Altération des Dépots superficiels par l'infiltration des eaux Météoriques, étudiés dans leurs rapports avec la Géologie stratigraphique*, par ERNEST VAN DEN BRŒCK, Conservateur au Musée Royale d'Histoire Naturelle, Attaché au service de la Carte Géologique. 180 pp. 4to, with a folded plate. Bruxelles, 1881. From vol. xliv of Mém. Couronnés et Mém. des Sav. Etr. of the Brussels Academy.—The facts and conclusions in this important memoir sweep away much that is erroneous in Quaternary stratigraphical geology. The principle appealed to is one well understood—that iron-oxidation and other metamorphic changes are carried downward into deposits, consolidated or not, by infiltrating waters; but the extent of the changes thus occasioned has not been so well appreciated. On this point the observations of the author throw much light. The diluvial deposits of many parts of western Europe have been described as consisting of "diluvium gris" below and "diluvium rouge" above; and the distinction has seemed to be of special importance by many recent writers. The author shows, and illustrates his facts by many sections, that the red beds are the gray beds turned red by oxidation through infiltering waters. His sections represent downward prolongations of the red into the gray, and layers of gravel of the gray beds continuously through the red without interruption or disturbance. In other cases gray beds are overlaid by yellow beds or gray clays by yellow clay deposits; and as before, the upper yellow bed is not a distinct bed, but a result of the superficial alteration of the gray through infiltrating waters producing oxidation. The large plate contains a number of colored sections of Quaternary deposits, fully sustaining his conclusions.

11. *On the application of a solution of mercuric potassium iodide in mineralogical and lithological investigations*, by V. GOLDSCHMIDT.—The ingenious method for separating mechanically the mineral constituents of a rock, proposed by M. Thoulet, has already been extensively employed by lithologists. This method is based upon the fact that a solution of mercuric iodide and potassium iodide in water may be obtained having a very

high specific gravity; and further that, by the addition of distilled water drop by drop, any required density, from the maximum (Thoulet) 2·77, down to 1, may be obtained. If now the fine fragments of a rock be introduced into the solution, those whose density is equal or less than that of the solution will float and all others will sink. By carrying on the process in a suitable vessel and by varying, as circumstances require, the density of the menstruum, the separation of several different minerals may be accomplished. For the further discussion of the subject, as given by M. Thoulet, reference must be made to his valuable memoir on "Contributions a l'étude des propriétés physiques et chimiques des minéraux microscopiques;" Paris, 1880 (also Bull. Soc. Min. France, ii, 17, 1881). This method has been exhaustively studied by Goldschmidt, and the results given in his memoir show how much can be accomplished in this way that was impossible by any of the earlier methods of mechanical separation; at the same time he calls attention to the conditions upon which success depends and to the various opportunities of error. The maximum density obtained by him was 3·196 but varying somewhat with the temperature. By the use of the solution Goldschmidt shows that with due care the specific gravity of a pure mineral in fragments can be obtained with an error of only 2 or 3 units in the fourth place of decimals. He determines in this way the specific gravity of a large series of specimens of different kinds of feldspar and concludes that the method gives a sure means of separating the different species of the group when fresh and pure. In regard to the best manner of separating the constituents of a rock the author gives many practical hints of value, and details the results obtained by him in a number of typical cases. It has also been proposed to use this solution of mercuric potassium iodide for various optical purposes as that of determining the indices of refraction by total reflection by the method of Kohlrausch. Goldschmidt finds the maximum index of refraction to be 1·73 (for D) and he has investigated the variation in refractive index for solutions of different strengths.—*Jahrb. Min.*, 1881.

12. *Deer horns impregnated with tin ore.*—Mr. J. H. Collins describes, in the Transactions of the Royal Geological Society of Cornwall, deer-horns, now in the British Museum, that were found in the tin-bearing gravel of the Carwon and Pentewan Valleys, which are impregnated with tin-ore, and seem to have, "in some parts, the original horn structure almost entirely preserved or reproduced in oxide of tin" and even contain in places visible crystals of this oxide. They are reported as having been formerly common and as having been sold as block tin to the smelters. These specimens have not been analyzed; but a fragment, belonging to the Cornwall Geological Society, which appears to be part of the horn of a *Cervus elaphus* (the red deer) afforded him on analysis 2·60 per cent. of stannic oxide, and 1·66 of iron sulphide; and, although the amount of these introduced ingredients is small, they were found, on microscopic

examination, to be distributed in the interior of each cell through the mass. Mr. Collins supposes that the tin was introduced by means of the fluoride.

13. *Microlite from Amelia County, Virginia.*—The rare species microlite, hitherto known only in minute crystals from Chesterfield, Mass., Branchville, Ct., and Utö, Sweden, has been recently found by Prof. W. M. Fontaine in Amelia County, Va., and is described by Prof. F. P. Dunnington. It occurs in isolated octahedral crystals from $\frac{1}{10}$ to $\frac{3}{4}$ inches in diameter and in larger crystalline masses, one of which weighed *eight pounds*. The physical characters are: H.=6 or a little less; G.=5·656; luster glistening resinous; color, wax yellow to brown; streak, pale ochreous yellow; sub-translucent; fracture conchoidal; very brittle. An analysis gave:—

Ta_2O_5	Cb_2O_5	WO_3	SnO_2	CaO	MgO	BeO	U_2O_3	Y_2O_3
68·43	7·74	0·30	1·05	11·80	1·01	0·34	1·59	0·23

Ce_2O_3, Di_2O_3	Al_2O_3	Fe_2O_3	Na_2O	K_2O	F	H_2O, deduct
0·17	0·13	0·29	2·86	0·29	2·85	1.17

O replaced by F
1·20 = 99·05

This shows the mineral to be essentially a calcium pyrotantalate. The formula deduced is — $\left\{\begin{matrix} 3(Ca_2Ta_2O_7) \\ (mCaWO_3) \end{matrix}\right\} + CbOF_3$.

—*Amer. Chem. Journal*, iii, 130, May, 1881.

14. *Mya arenaria.*—A paper in the American Naturalist for May last, by R. E. C. Stearns, reports that this mollusk, the "long clam" of eastern waters, has recently become the "leading clam" in the markets of San Francisco and Oakland, although unknown on the coast until the discovery of a few specimens on the eastern side of Francisco bay in 1874. How introduced is yet an unanswered question.

15. *Rhizopods, the food of some young Fishes.*—Dr. Leidy reports that the young of some of the suckers (Catostomidæ), *Hypentelium*, *Myxostema*, etc., have been found by Mr. S. A. Forbes, of Illinois, to have the intestines packed with tests of Difflugia and Arcella, indicating that they feed on Rhizopods. In a slide containing material from the intestines of the young Mullet (*Myxostoma macrolepidotum*) from Mackinaw Creek, prepared by Mr. Forbes, Dr. Leidy distinguished *Difflugia globulosa* and D. *acuminata;* and in another of the food of *Eremyzon succetta* he found *Difflugia globulosa*, *D. lobostoma*, *D. pyriformis*, *Arcella vulgaris*, *A. discoides*, besides another peculiar undescribed form.—*Proc. Acad. Nat. Sci. Phila.*, Jan. 4, 1881.

III. Astronomy.

1. *On the Figures of the Planets.*—The conclusions of Professor Hennessy in regard to the form of the planet Mars have been given on p. 162 of the last volume of this Journal (Feb., 1881). In a recent paper in the *Comptes Rendus* (1881, p. 225)

he gives the formulas deduced by him for the compression (e) of a planet resulting from superficial abrasion, and shows that this would be sensibly less than that resulting from the hypothesis of primitive fluidity. The application of the formulæ to the planets whose times of rotation and mean density are most similar to the earth give the following results:—

For the planet Mercury, if we admit 86700″ for its time of rotation, ·075 for the ratio of its mass to that of the earth, and ·378 for the ratio of its diameter to the earth's mean diameter, we find $Q=\frac{1}{406\cdot3}$; and if the planet were homogeneous,

$$e=\frac{1}{325}.$$

With the same law of density as in the earth, on the fluid theory,

$$e=\frac{1}{413};$$

and on the theory of abrasion,

$$e=\frac{1}{586}.$$

These three results show that for Mercury no sensible compression is likely to be observed.

For Venus, if we adopt the values of the mass M, time of rotation T, and diameter a, generally admitted, namely

$$M=\frac{1}{412150},\quad T=23^h\ 21^m\ 22^s,\quad a=\cdot954,$$

I find for the compression, on the hypothesis of fluidity and a law of density like that for the earth,

$$e=\frac{1}{247},$$

and by the hypothesis of abrasion at surface,

$$e=\frac{1}{351}.$$

The first of these values approaches closely to the compression recently observed by Colonel Tennant—namely, $e=\frac{1}{260}$. So far, therefore, the figure of Venus is more consistent with the theory of fluidity than with the theory of superficial abrasion.

Since I communicated my note on Mars to the Academy, I have become acquainted with the new determination of the planet's mass obtained from the motions of its satellites. The astronomers of the Washington Observatory have devoted especial attention to the satellites of this planet. Professor Asaph Hall has published results* which lead to the conclusion that the mass of Mars is probably about $\frac{1}{3093500}$.

With this value, and the values of other elements remaining

* Washington Astronomical Observations, xxii, Appendix.

the same as in my previous note, Q becomes $\frac{1}{203{\cdot}74}$ or $\frac{1}{204}$ nearly. The compression on the fluid theory becomes $\frac{1}{206{\cdot}96}$ or $\frac{1}{207}$. On the theory of abrasion the compression is $\frac{1}{303}$. The first is much nearer to the observed compression $\frac{1}{219}$ than the last.

It thus appears that, for the earth and the planets nearest to it, and whose mean density and general appearance make it probable that their materials resemble those of the earth in physical and mechanical properties, the compressions deduced from the theory of fluidity agree much better with observation than the compressions deduced from the theory of superficial abrasion.—*Phil. Mag.*, April, 1881.

2. *Observations of the Transit of Venus*, Dec. 8–9, 1874. Part I. Washington: Government Printing Office. 1880. Edited by SIMON NEWCOMB.—This is the first of four proposed parts in which the *Observations* made and reduced under the direction of the Commission created by Congress are to be published. The remaining parts will give the observations in detail, the discussion of the longitudes of the stations and the measures of the photographs with their reduction and discussion. The present part gives the general account of the operations and the reduction and results of the observations, and logically might have been the last instead of the first part.

The most important chapters are the third and fourth. The discussion of photographic instruments and measurements, and the formation of the observation equations fill the third chapter. There were over 200 photographs which could be measured, furnishing over 400 observation equations for determining the most probable corrections to the tabular place of the planet and the assumed solar parallax.

The discussion of the errors and discrepancies among the photographic results, and the determination of a value of the solar parallax are not given, as the Astronomische Gesellschaft has discouraged the publication of separate results for the solar parallax until the whole of the observations of all parties can be combined in a single discussion. The remark is made, however, that the probable error of the photographic measurements far exceeds what was originally estimated.

The fourth chapter gives a treatment of the contact observations, of which twenty-five were secured. These, also, are reduced to the form of observation equations, very like those from the photographs.

The lessons which these results furnish with reference to the observations of the transit in 1882 are not developed, but it seems probable that the photographic methods must be improved, or else not made our principal reliance in the coming transit. H. A. N.

3. *Observations of Double Stars made at the U. S. Naval Observatory;* by ASAPH HALL.—Professor Hall has given in

this memoir the results of his observations on double stars with the twenty-six inch equatorial of the Naval Observatory, made during the five years, 1875–9, together with a few measures made in 1863, with the 9.6 equatorial.

A group of observations is first given on selected stars, made in concert with Mr. Struve and Baron Dembowski, for the purpose of eliminating constant errors of position angle if possible.

A series of measures upon two triple stars and upon the trapezium of Orion, give further means of estimating the accuracy of Professor Hall's measures with the great equatorial. The main part of the memoir is devoted to the measures of other double stars. The total number of observations is 1,614 on over 400 different stars. When we consider that one good observation of a double star is worth scores of those of moderate or doubtful value, we appreciate more highly the value of such a series of observations by such an observer. H. A. N.

IV. Miscellaneous Scientific Intelligence.

1. *Historical Sketch of the Boston Society of Natural History, with a notice of the Linnæan Society which preceded it;* by Thomas T. Bouvé. 250 pp. 4to, with several portraits. From the Anniversary Memoirs of the Boston Society of Natural History, published in celebration of the Fiftieth Anniversary of the Society's foundation.—This volume comprises an important part of the history of American science. The Linnæan Society, which was the predecessor of the Natural History Society, was begun in 1814, at first under the name of The New England Society of Natural History, but a month later, that of the Linnæan Society of New England, and in 1823 its last meeting was held. When the Boston Society of Natural History commenced, in 1830, it acquired possession of what remained of the collections of the Linnæan Society, but "nothing of any considerable value was obtained." The society was without endowment, and the income for the first year from the fees of members and a course of lectures, after deducting the expenses of the lectures, was but little over five hundred dollars. Through the liberality of its friends, it now has a fund of more than $150,000, a building that cost as much as this, a large library, extensive collections, and many volumes of its own published Memoirs and Proceedings. Considering the expenses of publication, of the care of specimens, the great importance of extending the collections, and the required outlays for curators, librarian, and other urgent needs, the amount is still small; and yet that it is so much is an honor to the generous citizens of Boston, who are sure to keep making it larger. Mr. Bouvé, in his excellent history of the society, gives the details of the society's progress and a general account of the work it has accomplished. The volume contains, also, brief, life-like sketches of the members that have died, among whom are a number that will be long remembered in science—Dr. Benjamin D. Greene, Amos Binney, Dr. Burnett, Dr. Warren, Dr. Harris, Dr. Gould, Charles Pickering, Agassiz,

Wyman. Dr. Wyman was president for fourteen years (from 1856 to 1870), and, like Agassiz, was a man to be ever kept in mind for his excellencies by future generations of laborers in science. The Boston Society of Natural History owes much to the author of this volume for the faithful and judicious manner in which it has been prepared.

2. *American Association at Cincinnati.*—The next meeting of the American Association for the Advancement of Science opens at Cincinnati on the 17th of August. Professor GEORGE J. BRUSH, of New Haven, Conn., is President of the meeting; Professor A. M. MAYER of Hoboken, N. J., Vice-President of Section A.; F. W. PUTNAM, of Cambridge, Mass., Permanent Secretary, and C. V. RILEY, of Washington, D. C., General Secretary. The Chairman of the Subsection of Chemistry is W. R. NICHOLS, of Boston, Mass.; of Microscopy, A. B. HERVEY, of Taunton, Mass.; of Anthropology, GARRICK MALLERY, of Washington, D. C.; of Entomology, J. G. MORRIS, of Baltimore, Md.—The headquarters of the Association in the city will be at Music Hall; there will be found the offices of the Permanent Secretary and Local Committee, as well as the rooms for the sessions, and the book for registering the names of members on their arrival.

3. *On the so-called Cosmical Dust.*—Dr. LASAULX has investigated the subject of the mineral dust which at different times has been collected at various points on the earth's surface and for which a cosmical origin has been assumed. The memoir by Nordenskiöld on this subject, noticed in this Journal, ix, 145, 1875, is reviewed and some of the conclusions there reached questioned. A portion of the original material from the interior of Greenland, named by Nordenskiöld *cryoconite*, was examined microscopically and was found to be not even approximately homogeneous. On the contrary, the dust was made up of particles of quartz, mica, orthoclase and triclinic feldspars, magnetite, garnet, epidote and hornblende, and, with these, brown or brownish-green particles of organic nature probably microscopic algæ. Dr. Lasaulx concludes, from the absence of augite and chrysolite, that the dust could not have come from a volcano, but that it was derived from the gneissoid rocks on the coast of Greenland; that there is no reason to think of a cosmical origin for it, and the presence of quartz and mica declare against this idea. The dust of Catania, Sicily, which was described by Silvestri and has been regarded as cosmical, Lasaulx has also investigated. His conclusion is that all the materials present in it could have been, and in all probability were, derived from Mt. Etna. A study of the residue obtained by the melting of a large quantity of snow collected by the author in the neighborhood of Kiel revealed no minerals for which anything but a terrestrial source need be predicated. In conclusion, Lasaulx decides that the atmospheric dust is in general to be regarded as terrestrial detritus, and that before a non-terrestrial origin can be considered proved in any case, a much more critical microscopic examination must be made than has been customary in the past.